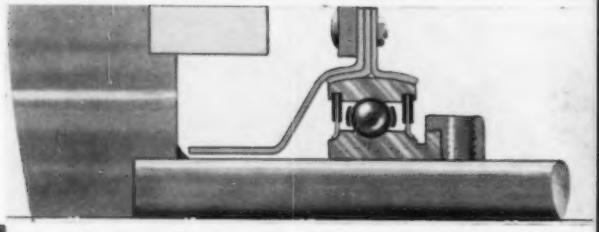
MARCH 1958

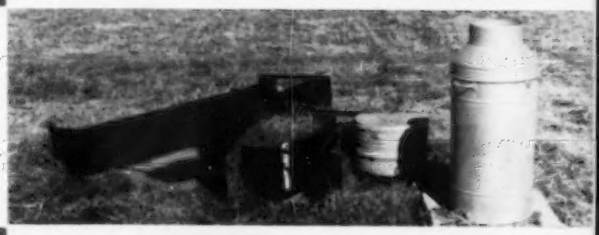
Agricultural Engineering

The Journal of the American Society of Agricultural Engineers

Trends in Ball Bearing Design for Farm Machinery | 152

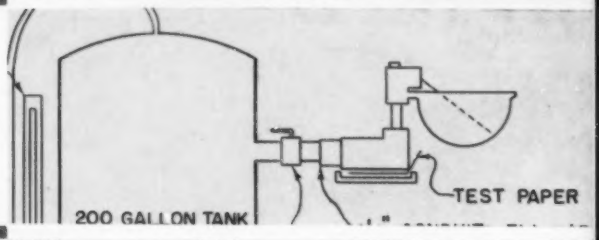


Comparing Irrigation Water Application Efficiencies | 156

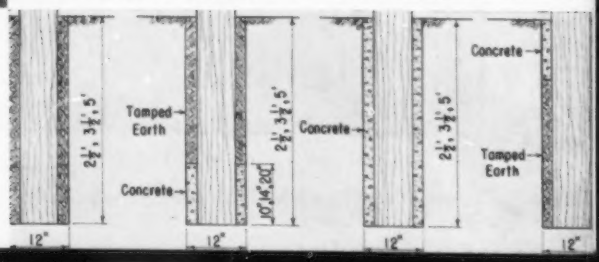


Resistance of Seed Cotton to Air Flow | 160

Back Siphonage Testing of Livestock Watering Devices | 164



Stability of Poles Under Tilting Moments | 166



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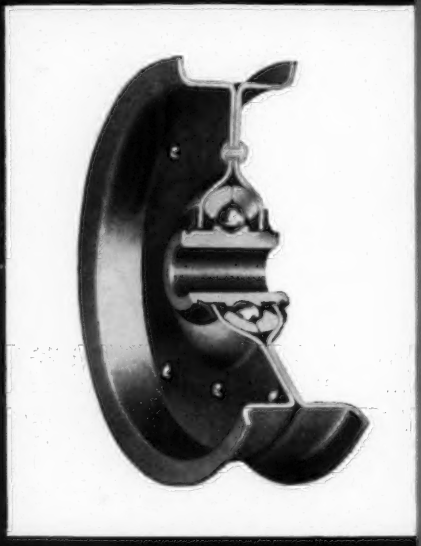

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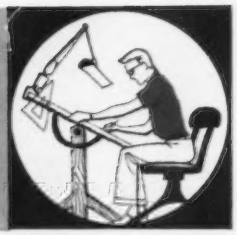
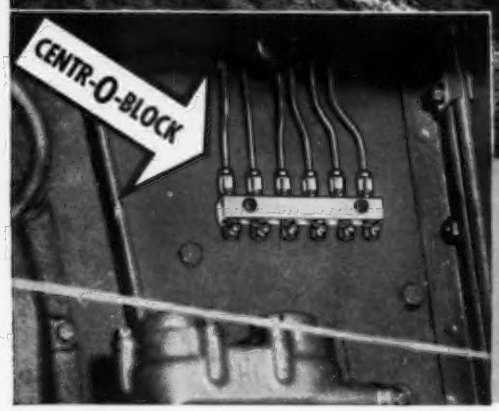
No. 108 of a series of case histories on the vital role of lubricant application systems in engineering design.





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Agricultural Engineering

Established 1920

CONTENTS • March, 1958 • Vol. 39, No. 3

Report to Readers 137

ASAE Motion Picture Project 151

Trends in Ball Bearing Design for Farm Machinery . . 152
R. S. Howe, Jr. and G. H. Raley

Comparing Irrigation Water Application Efficiencies . . 156
B. R. Somerhalder

Resistance of Seed Cotton to Air Flow 160
T. J. Nissing

Back Siphonage Testing of Livestock Watering Devices . 164
J. S. Boyd and W. H. Sheldon

Stability of Poles Under Tilting Moments
Part I — Experiments and Results 166
G. L. Nelson, G. W. A. Mahoney and J. I. Fryrear

Concepts, Terms, Definitions and Methods of Measurement for Soil Compaction—Joint ASAE-SAA Soil Compaction Committee Report 173

News Section 177

New Products 180

Manufacturers' Literature 190

Index to Advertisers 196

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Materials Handling Conference

THE American Society of Agricultural Engineers is sponsoring its first national Materials Handling Conference devoted specifically to agricultural products. The conference will be held Sept. 17-19 at Iowa State College.

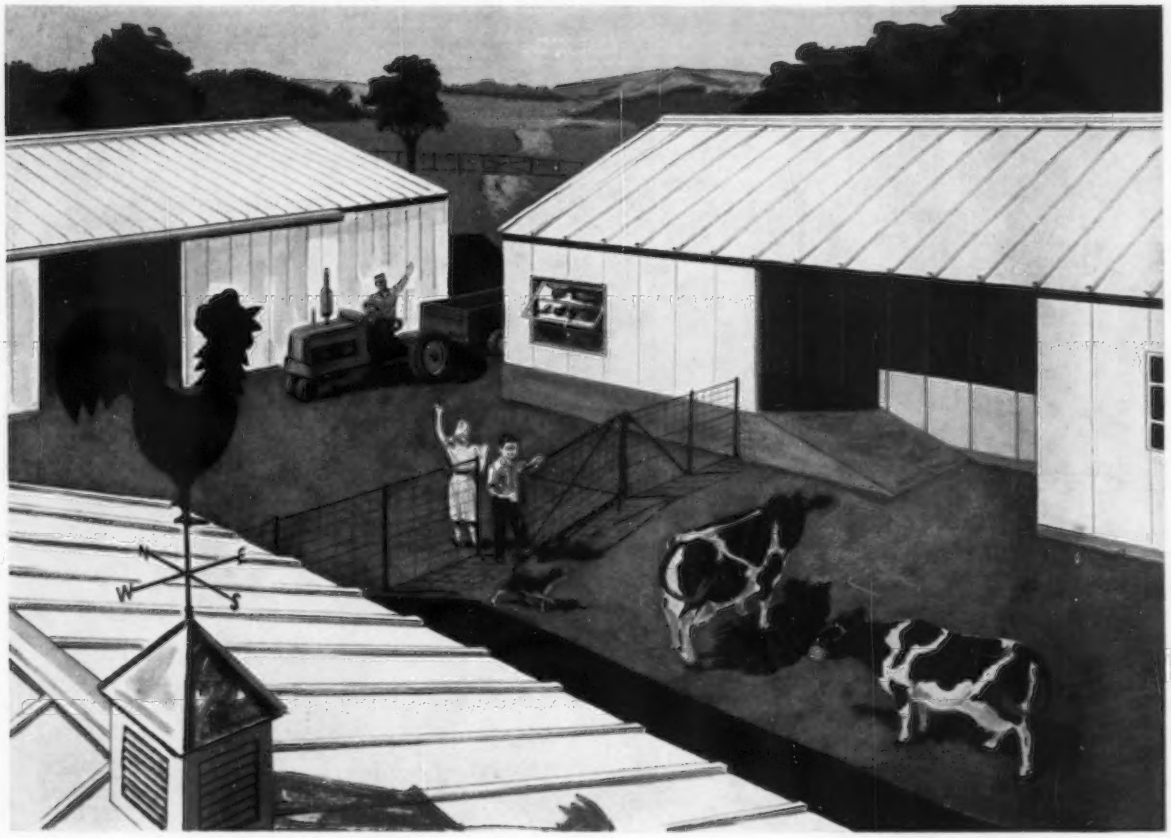
The objectives of the conference are to stimulate and encourage basic, systematic progress among colleges, industries, power companies, and others in the development of materials handling methods for farms; to provide a reference for agricultural engineers, manufacturers, dealers, and farmers on the subject; and to establish the American Society of Agricultural Engineers and the agricultural engineering profession as the authoritative source for agricultural materials handling information.

The program is designed to be of interest to agricultural engineers, manufacturers and dealers of buildings and equipment for storing, processing and handling agricultural materials, power suppliers, and farmers. It will include all materials farmers handle including hay, silage, grain, ground feed, water, manure, products farmers buy, and products farmers sell.

Following a 2-day technical conference the annual Agricultural Engineering Field Day sponsored by the agricultural engineering department of Iowa State College will be held. The program will be devoted to the materials handling theme and the principles established during the technical sessions will be applied through actual demonstrations of practical systems. Preliminary plans call for actual crops to be grown in front of the demonstration area and materials handling equipment set up so that agricultural materials handling can be demonstrated from "field to storage, through processing, to livestock, to market." There will also be an exhibit area provided for display of equipment. Information on display space may be obtained by writing to Norval Curry, Agricultural Engineering Dept., Iowa State College, Ames.

The September issue of AGRICULTURAL ENGINEERING will be devoted entirely to farm materials handling and by reason of the scope of the material it will contain, including all papers presented at the conference, promises to be a comprehensive handbook on agricultural materials handling suitable for the engineer, manufacturer, dealer and farmer alike.

The program will open with an introduction which will cover the present status of materials handling, what is available to do the job, and progress that has been made. Three speakers will discuss the handling of unit (batch) materials by their physical characteristics — liquid, free flowing and non-free flowing. During the second day each of four types of materials will be handled separately. Three speakers will report on liquid materials — one on water, one on milk, and the other on fertilizer, liquid manure, liquid feeds, sprays, fungicides, herbicides, etc. Free flowing materials, including grains, pelletized materials and others, will be covered in one paper. A paper on hay and manure, another on silage, and one on supplement ground feed, fertilizer and ear corn are scheduled to cover the non-free flowing materials. Two speakers will report on unit (batch) materials covering bales, sacks, pallets, loads, stacks and others. A detailed engineering analysis of an actual installation is planned and the program will be concluded with a talk on the job ahead for materials handling.



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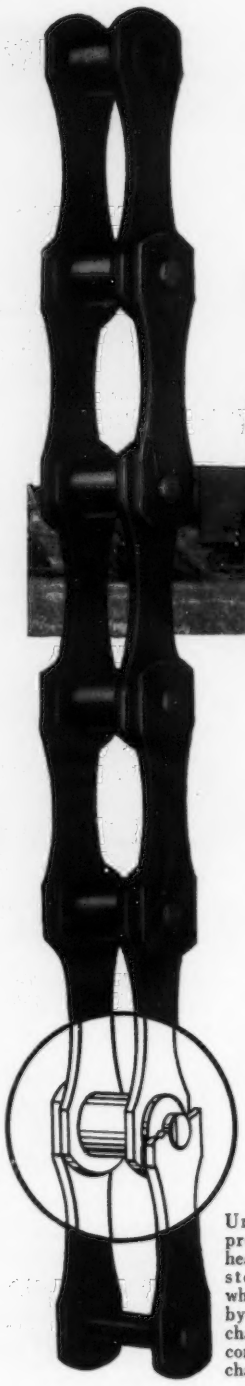
LET THE DUST FLY



Under operating pressures bushing heats and releases stored lubricant which is reabsorbed by bushing when chain is idle. Cycle continues for life of chain.

WHITNEY SELF-LUBE AG CHAIN

keeps farm equipment continuously operating without chain maintenance.

Under conditions of extreme dust or mud, it will outlast regular chain by as much as five to one.

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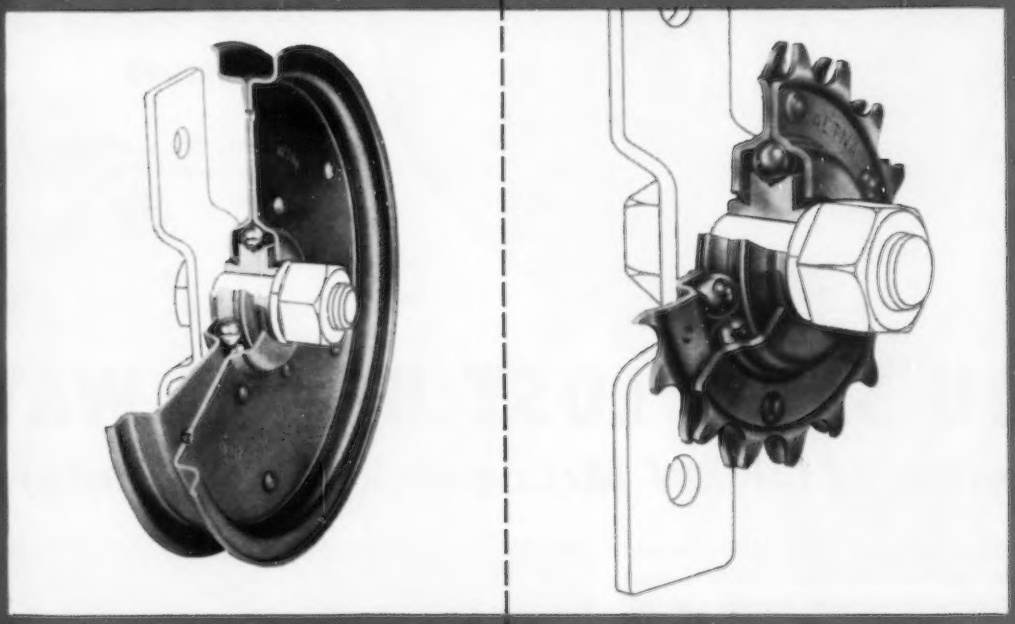

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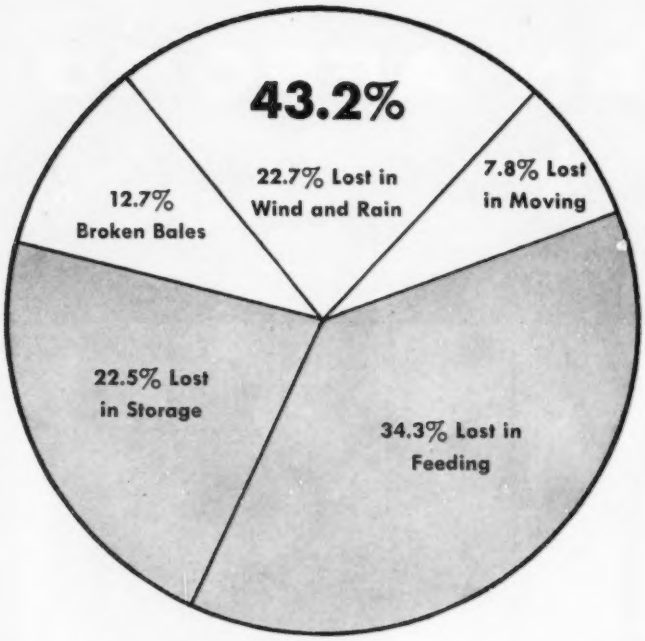

AG COLLEGE SURVEY SHOWS 43.2% OF HAY LOSSES OCCUR IN HARVESTING

From Circular 203, Montana State College Agricultural Experiment Station.

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In a leading grassland state, 43.2 per cent of all hay lost between field and feed bunk can be charged to weather damage and baling waste. Now, with new low-cost McCormick No. 46 hay baler, farmers can save much of this "lost hay." It's simple as 1, 2, 3:

1. **Extra-capacity beats bad weather.** Owners report the No. 46 bales as much as 13 tons an hour to outdo everything in its class! Now, more of every crop can be choice feed relished by livestock.

2. **Timely baling** and gentlest handling yet save more vitamin and protein-rich leaves for feeding, to cut meat and milk costs.

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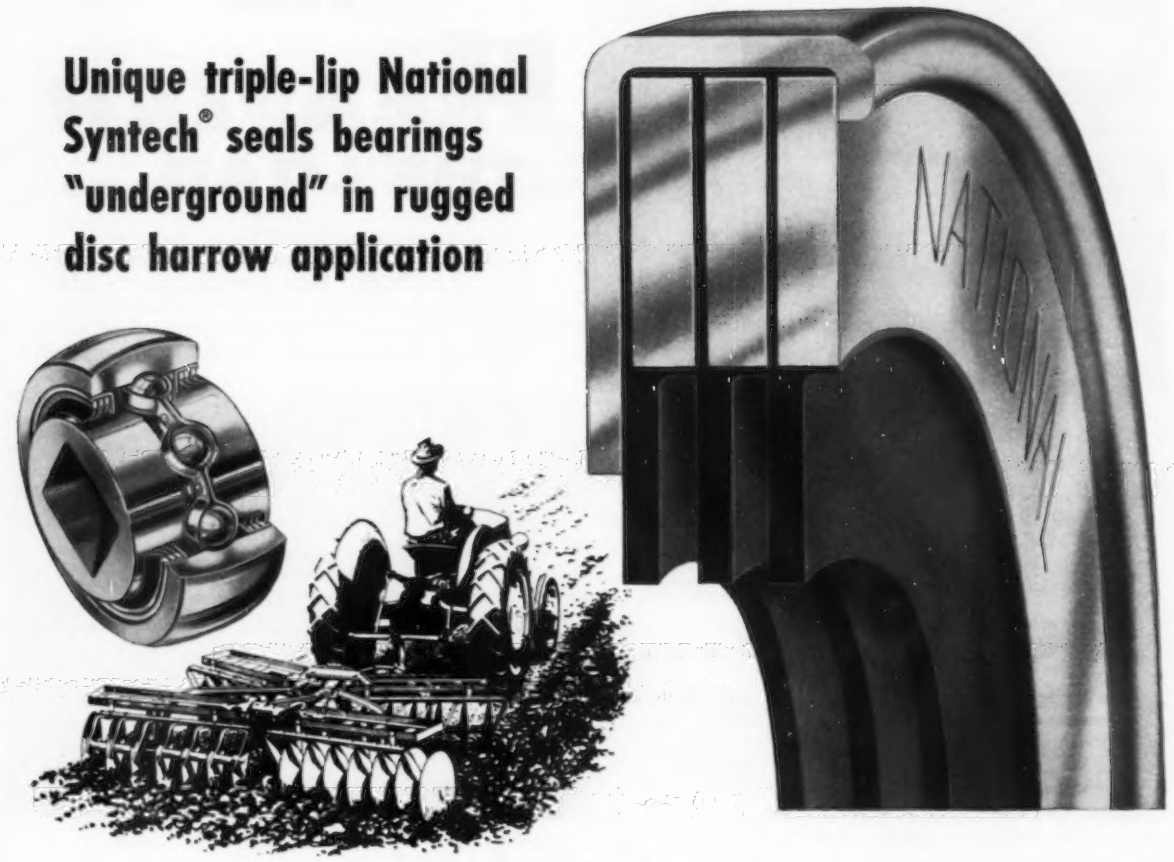

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The seal is rugged and extremely simple in design. It consists of three identical synthetic rubber sealing members bonded to metal washers and enclosed in a rigid steel outer case. Use of the "straight" Syntech sections keeps torque low, simplifies flush lubrication, and permits the seal to accept a high degree of runout and misalignment where needed.

For complete information, call your National Applications Engineer or write direct

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Division, Federal-Mogul-Bower Bearings, Inc.
General Offices: Redwood City, California
Plants: Van Wert, Ohio, Redwood City and Downey, California

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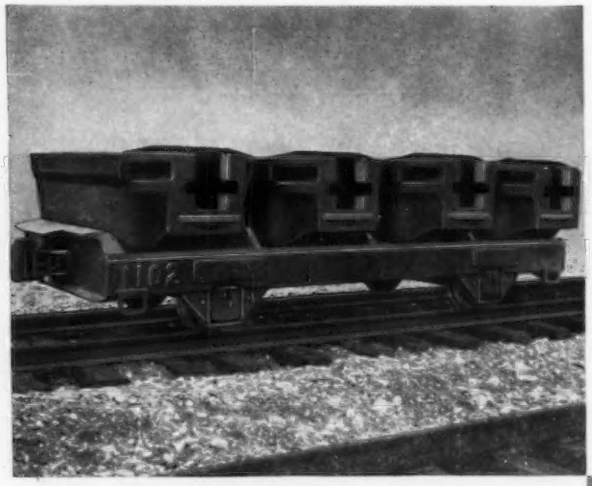

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the more you need HYATTS . . . because nothing can compare with the cylindrical roller bearing for rugged, load-carrying capacity and continuous operation under adverse conditions. That's why leading steel mills specify HYATT Hy-Rolls for applications like these charging cars.

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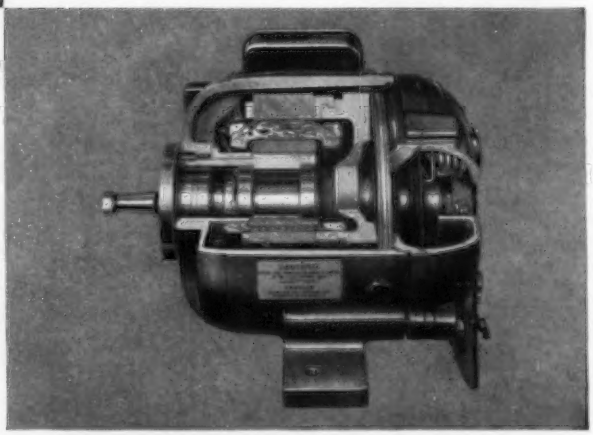
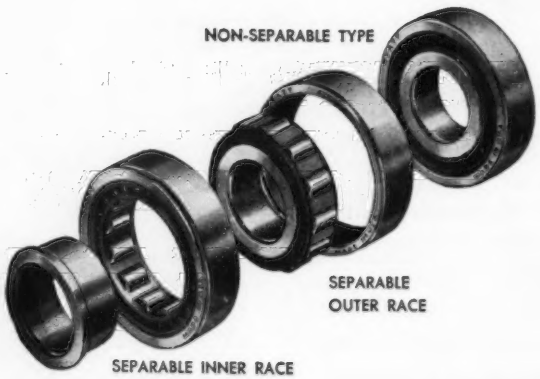


THE MORE YOU NEED *Cylindrical* HY-ROLL BEARINGS



Today, as new industrial designs require heavier loads and higher speeds crammed into smaller housings, engineers are turning to HYATT Roller Bearings, America's most complete line of cylindrical roller bearings. They find their problems are solved quickly with bearings like the shouldered-race HYATT Hy-Roll that will handle heavy radial loads while taking a surprising amount of thrust. Contact your nearest HYATT Sales Engineer for recommendations—You'll find him a mighty big help! Hyatt Bearings Division, General Motors Corporation, Harrison, N.J.; Pittsburgh; Detroit; Chicago; Oakland, California.

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HYATT HY-ROLL BEARINGS FOR MODERN INDUSTRY

Report to Readers . . .

MATERIALS HANDLING IN AGRICULTURE PRESENTS NEW ENGINEERING CHALLENGE

It was when transmission lines started feeding electric current out along the highways and byways of rural America, and the busy hum of the electric motor began to help with the farm chores, that mechanization of materials handling in agriculture got its first humble start. In fact, electrification must be credited with starting this ball rolling. Now, it is literally "snowballing". . . . . However, it was but a few short years ago that students of the situation were pointing to the disparity between the rapid pace in mechanizing field operations as compared with the lack of a similar development in the case of farm chore jobs. But that picture is undergoing rapid change; the mechanization of materials handling, in practically all its phases, is moving ahead full tilt. Driving forces behind this development are (a) hard-pressed farmers faced with growing labor shortages and mounting production costs; (b) engineers in the state and federal agricultural extension and research agencies; and (c) engineers in related manufacturing organizations that are developing and building the equipment essential to every farm materials-handling need. . . . . To provide some measure of the stimulus essential to further enhance this development, the American Society of Agricultural Engineers is sponsoring a two-day "Farm Materials Handling Conference" to be held at Iowa State College, at Ames, on September 17 and 18. More details on the Conference will be found elsewhere in this issue, and the complete proceedings of the Conference will be published in the September issue of this journal.

SELF-PROPELLED COMBINES TAKE LEAD OVER PULL-TYPE MACHINES

In the case of large units especially, it is becoming more and more apparent that the self-propelled type of equipment continues to gain in popularity over the pull-type. In the case of the grain combine, for example, an International Harvester executive recently stated that last year his company, for the first time, sold more self-propelled than pull-type machines. This trend is likely to continue since the former type machine has one big advantage over the latter, in that the operator has more precise control over the machine itself as well as the work it is doing. Also, the self-propelled machine usually frees a tractor for other farm work during corn harvest. . . . . Many engineering minds throughout industry are busy discovering and developing additional functions for existing machines. A typical example is that of using a corn head on the combine to "combine" the corn crop. Engineers are also in process of developing corn pickers that, in addition to picking and husking the corn, will shell it in the field as well.

NEW METHOD FOR THE CONTROL OF EVAPORATION FROM FARM PONDS

A major problem confronting engineering specialists in soil and water conservation in agriculture is how to retard evaporation from open water surfaces. These engineers have tried several physical means for this purpose with varying degrees of success. What now appears to be a most likely solution to the problem is the application of fatty alcohols to water surfaces. In fact, the U S Secretary of the Interior has referred to this means of evaporation control as one of the most promising areas of water conservation. Extensive tests by the Southwest Research Institute and the USDI Bureau of Reclamation not only highlight the efficiency of fatty alcohols to control evaporation, but also establish the fact that they are harmless to humans, livestock, fish and plant life. . . . . It is known that on much of the land area of the United States, evaporation exceeds precipitation. In parts of two southwestern states, for example, the annual evaporation loss from ponds and reservoirs is as much as 10 vertical feet, according to U S Weather Bureau records; and even in Iowa, where precipitation is normally more than

adequate, evaporation losses range between 3 and 4 feet during the frost-free season. . . . . Thus far the use of fatty alcohols to control evaporation has been applied most successfully on rather small bodies of water, up to two acres, say, in area. On areas of this size, and with adequate means for re-sealing breaks in the fatty alcohol film on the water surface, reductions in water evaporation up to 60 percent have been obtained. Further research is now under way to adapt this method successfully to larger bodies of water, such as large ponds, reservoirs, and even small lakes.

MACHINE LIKELY TO REVOLUTIONIZE THE ECONOMICS OF POTATO GROWING

A new British potato-planter fertilizing mechanism, it is claimed, will save one-third of the fertilizer required in conventional planting methods. This device, when built into a particular make of planter, makes it possible to open the furrow, plant the potato set, fertilize, and cover the furrow in one continuous operation. . . . . As each potato set is placed in the furrow, it is covered with a thin layer of soil, and a ring of fertilizer is dropped around it. The device also distributes this ring of fertilizer so that it is thinner on the inner portion of the ring and heavier on the outer. In this way, the tender new roots feed lightly at first and then reach for a richer diet as the plant grows. Another feature of the machine is that any pressure on the soil, in which the potato is growing, is completely avoided, since neither the tractor nor the planter wheels run over it.

MASTER CHECK LIST HELPS PROTECTION OF FARM PROPERTY AGAINST LIGHTNING

The Lightning Protection Institute, we think, is rendering an important service to farm people in the distribution of what it calls a "Master Check List" for all farm lightning protection installations. The LPI points out that lightning is the largest cause (37 percent) of farm fires, not to mention deaths and injuries by the hundreds, as well as various types of property damage estimated at more than 100 million dollars a year. (The lightning death toll - around 600 a year and much greater than from floods, tornadoes, and other natural forces - is concentrated in rural areas.) . . . . The Institute states that virtually complete protection from lightning-caused fires or from structural damage by a "cold" bolt can be given to farm structures by means of a properly installed and grounded lightning-rod system. . . . . Despite the devastation that can result when lightning strikes, it can be controlled - by proper installation of rods, conductors, and grounds - so that its great force is dissipated harmlessly into the air or ground. Use of the LPI Master Check List will help tremendously to reduce farm damage due to lightning. . . . . In this connection, LPI issues this important warning: Authorities on lightning protection say that simple grounding of the siding and roofs of metal-clad buildings will not protect them from lightning damage, and that such structures should have the same type of lightning-protection system and installation as approved for buildings without metal roofing or siding.

FLOATING PUMPING STATION DRAINS FARM LAND LYING BELOW SEA LEVEL

To prevent flooding by salt water of valuable farm land lying below sea level around the river estuaries on England's east coast, an English agricultural consultant designed a floating pumping station for the purpose. It consists of an electric-motor-driven, axial-flow pump installed in a cylindrical steel tank that floats on the surface of an artificial lagoon just inside the river wall. Flexible connections link this floating pontoon to a discharge pipe which runs through the embankment to discharge into the river. Aside from providing a mooring point and connection to an electric power supply, the discharge pipe is the only construction work required at the site. The total cost of the installation is only about one-half that of the standard type. Its big advantage is the simplicity of design, which makes it cheap and easy to install and virtually foolproof to run.

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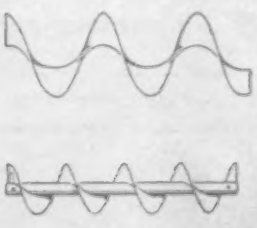
WHERE augers are a vital part of any equipment, here's the sure way to better equipment design. Link-Belt augers are available in a full range of diameters, gauges and pitches . . . in any suitable metal to meet your exacting requirements. They're simple and compact, accurately made to insure dependable operation.

For any design problem involving augers ask the Link-Belt office near you for engineering assistance.



SELECTED FLIGHTING for all your auger needs. Helicoid, sectional or a range of other types are available in the metal and finish best suited for your design.

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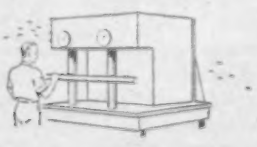

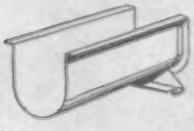

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ENGINEERING SERVICES. Our auger specialists will help to analyze your special needs . . . integrate all elements of your design for overall system efficiency.

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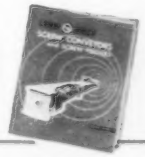
FARM MACHINE AUGERS

Get in touch with the nearest Link-Belt office for your copy of Screw Conveyor Data Book 2289 . . . today.



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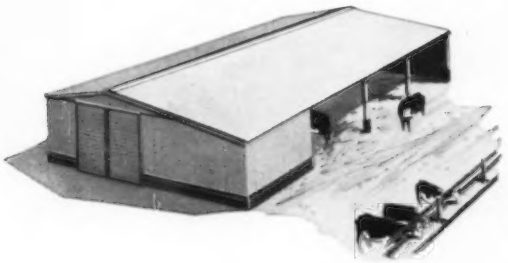
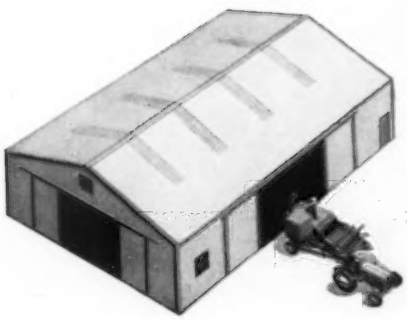
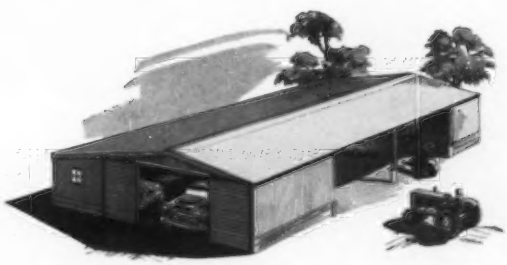


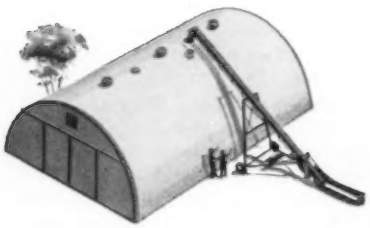
Stran-Master—Lowest cost all-steel farm building. Pole-type design makes erection fast and simple. Choice of do-it-yourself construction or dealer's crew. Buildings from 12- to 120-ft. width . . . any length in 16-ft. multiples . . . 10- or 14-ft. eave heights. Wall designs may be open, totally enclosed or partially enclosed. Stran-Master gives more for less money . . . ideal for machinery storage, livestock housing and general utility storage.



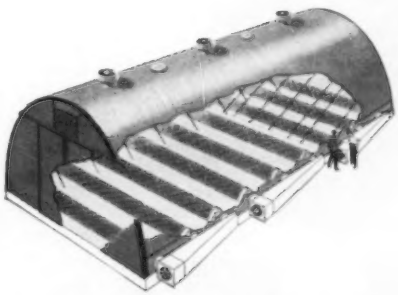
Rigid Frame Building—Meets all requirements for a service and repair center . . . big doors for machinery access . . . clear-span interiors for unrestricted working space and fire safety. Easy to insulate. Durable all-steel construction lasts for decades.



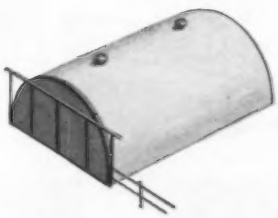
Stran-Master—Weather-tight all-steel construction gives lifelong protection to valuable farm machinery. Saves depreciation losses and keeps machinery in top condition. When storage requirements grow, building may be easily enlarged at minimum cost without loss of materials.



Quonset 40—Most dollar value in a farm building! Post-free storage for machinery and farm crops. Ideal for livestock. And it's designed for the Quonset Grain Drying System.



Quonset Grain Drying System—Saves at least 15% because you get a drying system as well as a cooling system with your Quonset storage building. Drying costs are less! Building widths of 20′, 32′ and 40′.



Quonset 20—A workhorse for economy! Ideal for grain storage, and available with Quonset Drying System. Serves as handy utility building for seed, feed, fertilizer and other supplies.

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Atlanta 3, Ga., 206 Volunteer Bldg.; **Cleveland 16, Ohio,** 20950 Center Ridge Rd.; **Detroit 29, Mich.,** Tecumseh Rd.; **Houston 25, Texas,** 2219 Bellefontaine; **Minneapolis 4, Minn.,** 708 So. 10th St.; **New York 17, N.Y.,** 405 Lexington Ave.; **San Francisco 3, Cal.,** 1707 Central Tower Bldg.; **Washington 6, D.C.,** 1025 Connecticut Ave., N.W.

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Detroit 29, Michigan • Division of
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Easy to Finance—*Stran-Steel Purchase Plan permits confidential finance arrangements between you and your dealer—leaves bank credit free for normal farm needs. Fast credit approval. As little as ¼-initial investment and five years to pay balance.*

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THE FINEST ENGINEERED MACHINERY IN THE AGRICULTURAL FIELD IS EQUIPPED WITH

SEALMASTER BALL BEARING UNITS

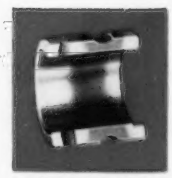
SEALMASTER'S EXCLUSIVE COMBINATION OF FEATURES ASSURE TOP PERFORMANCE

Although many times the bearing units on a piece of farm machinery may be hidden from the eye, they're one of the first components to show up performance-wise. It's what you can't see on the surface — the hidden engineering features — that benefit you most with a ball bearing unit, too.

Every agricultural engineer will want to become acquainted with SEALMASTER'S exclusive combination of features. They provide a decided performance-advantage for the machinery you design. Get full particulars from the SEALMASTER representative in your area or write . . .

LOCKING PIN & PERIMETER DIMPLE . . . prevents rotation of outer race, assures positive lubrication.

LABYRINTH SEAL . . . keeps dust and dirt out and lubricant sealed in, assuring long bearing life.



ZONE HARDENING . . . assures positive race to shaft holding power. Reduces corrosion.

You'll want a copy of SEALMASTER Bulletin 454.

SEALMASTER®
BALL BEARING UNITS

SEALMASTER BEARINGS A DIVISION OF STEPHENS-ADAMSON MFG. CO. 67 RIDGEWAY AVENUE, AURORA, ILL.

Here's how Alcoa helps you help farmers

When problems concerning farm uses of aluminum arise, Alcoa has a 70-man research team ready to tackle them.

Out of Alcoa research has evolved aluminum farm gates that need no upkeep; longer-lasting aluminum irrigation pipe; and pole-type aluminum buildings that stay up to 15° cooler and save up to 75% on construction.

While farmers have heard of these products, they still may ask many questions about them. Alcoa would like to provide you with helpful background material on farm applications of aluminum. We've listed at right some of the current information available.

In addition, we'd like you to feel free to bring special aluminum application problems to our attention. From the enormous mass of practical information at our disposal, we usually can help you. Write us any time.

"ALCOA THEATRE"
Exciting Adventure Alternate Monday Evenings

Your Guide to the Best in Aluminum Value

ALCOA ALUMINUM FARM PRODUCTS

Agricultural Division,
Aluminum Company of America,
2089-C Alcoa Building, Pittsburgh 19, Pa.

Please send items checked.

- ☐ Alcoa Farm Gate Literature. The story of aluminum gates.
- ☐ "Right As Rain." 28-minute sound-color film on irrigation.*
- ☐ "Barn Raising, U. S. A." 18-minute sound-color film on how to build low-cost aluminum pole barn.*
- ☐ *Pole Barn Plans Catalog.* Catalog of nine pole-building plans available to farmers.

*Films may be borrowed for group showings. Specify dates wanted.

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For more facts circle No. 14 on reply card

John Deere Equipment Makes Hay the One-Man Way!

Revolutionary Bale Ejector Attachment Loads Wagons Automatically... Elevator and Barn Bale Conveyor Store Bales Automatically!

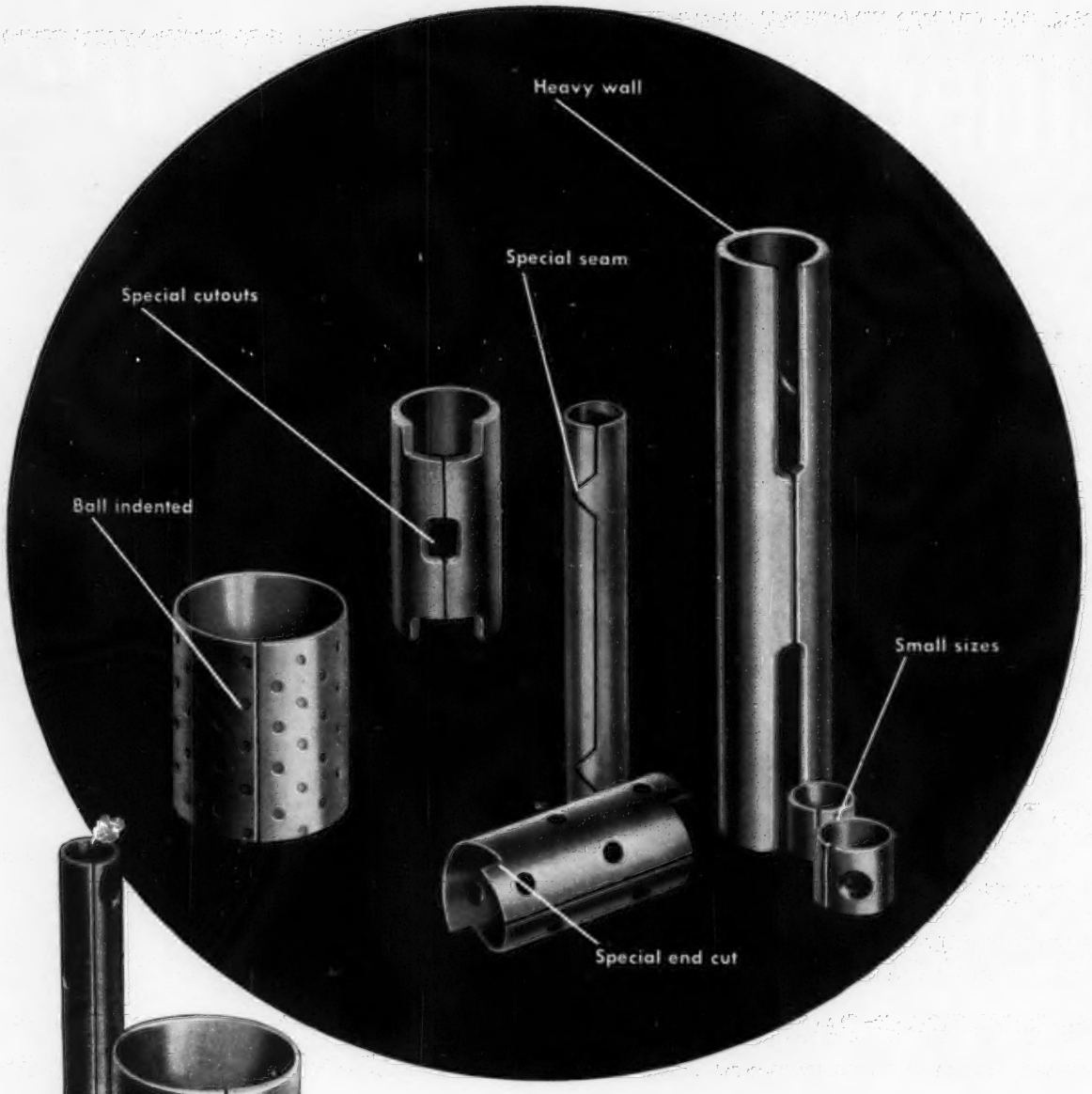
Once upon a time farmers were dependent upon extra help for hay making. One man couldn't handle the job alone. He could mow, condition, and rake—but he couldn't handle the baling and storing job on his own. *Others* had to load the bales on the wagon or pick them up from the field. *Others* had to lift and stack the bales in the stifling heat and dust of the mow.

So, John Deere engineers said, "We'll make haying a one-man job. We'll eliminate the baling crew except for the tractor driver. We'll eliminate the men in the mow—the tractor driver can store his own hay as he brings it from the field."

And, they did it! Now haying *is* a one-man job, thanks to the revolutionary John Deere Bale Ejector Attachment for John Deere 14-T and 214-T Twine-Tie Balers . . . thanks to the John Deere Elevator and Barn Bale Conveyor. Every hay grower who feeds his hay profits in time and labor saved . . . in better crops in the barn.

JOHN DEERE
MOLINE, ILL.

"Wherever Crops Grow, There's a Growing Demand for John Deere Farm Equipment"



Rolled split spacer tubes are produced in a wide variety of standard and special designs, in many lengths and diameters, of steel, brass and aluminum. They can be ball-indented for oil pockets, or made with oil holes or other special cutouts or seams.

FEDERAL-MOGUL DIVISION

Federal-Mogul-Bower Bearings, Inc., 11081 Shoemaker, Detroit 13, Michigan

Rolled, Split Bushings

Engine Bearings

Bimetal Bushings

Bearing-Surfaced Thrust Washers

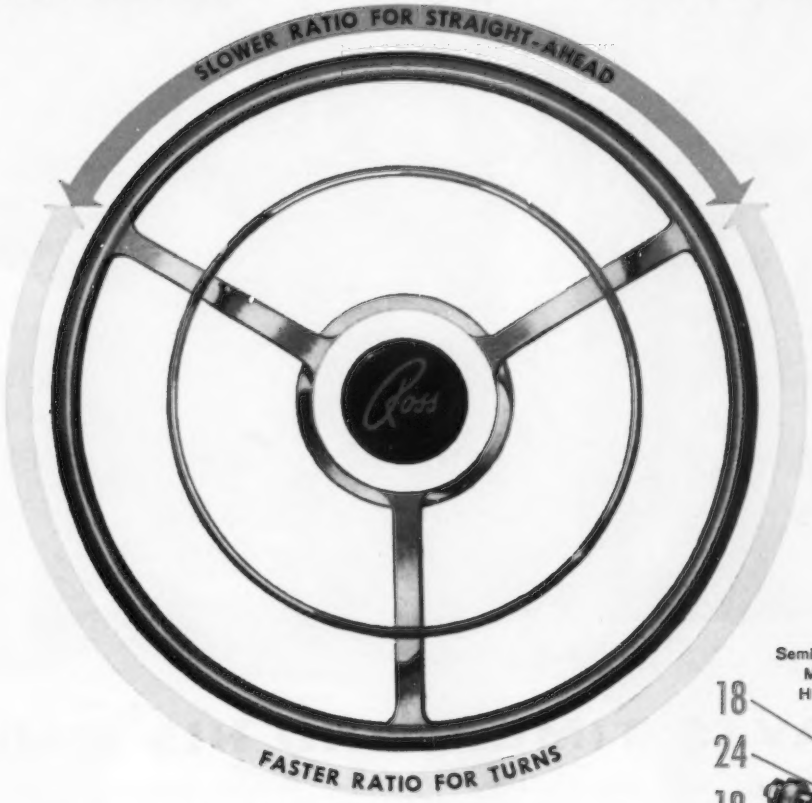
FEDERAL Mogul

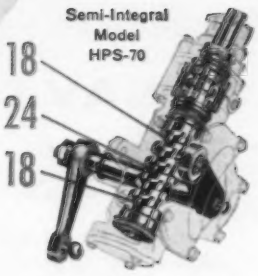
Since 1889

RESEARCH • DESIGN • METALLURGY • PRECISION MANUFACTURING

For more facts circle No. 16 on reply card

VARIABLE-RATIO STEERING





For example 18 : 24 : 18 . . .

▶ **You'd need two** steering gears of any other type, or make, to match the response, stability and maneuverability that Ross provides with one *variable-ratio* unit.

The ratio variation, of course, can be whatever your steering job requires. For example 18:24:18 would give you an 18 to 1 ratio for faster steering and quicker recovery for turns, and a 24 to 1 ratio for slower steering and almost hands-off stability for high-speed, straight-ahead handling where most driving occurs.

▶ **Again,** variable ratio is an exclusive feature of Ross Hydra-power power steering and Ross Cam & Lever manual steering. No other type, or make, of steering gear provides it.

▶ **Ross manufactures all three types** of power steering: integral, semi-integral and linkage. And invites discussion of any steering problem, power or manual, variable or fixed ratio.

Ross

HYDRAPOWER

ROSS GEAR & TOOL COMPANY, INC. • LAFAYETTE, INDIANA
Gemmer Division • Detroit

For more facts circle No. 17 on reply card

SAVES TIME...AND HIS BACK

KENNETH RIPPEL, (right) progressive farmer of Asbury, Mo., rigged up this self-unloading feed truck to save himself some back-breaking labor.

He put an old lime spreader box on a truck chassis and connected to the transmission power take-off to drive the conveyor. The conveyor elevates feed to the troughs. He saves more labor by using a hydraulic loader to put feed into the box.

Mr. Rippel, shown here with Texaco Consignee G. W. Edge, Pittsburg, Kan., is a booster for Texaco products, including Fire Chief gasoline. He likes its superior fire power which results in low cost operation of machinery. Like good farmers in all 48 states, he knows *it pays to farm with Texaco products.*

TEXACO CONSIGNEE C. E. Gripe delivers Marfak lubricant to W. J. Sylvester, of Battle Creek, Mich. Mr. Sylvester prefers Marfak because it gives better protection to bearings of farm machinery. It forms a collar around open bearings—won't drip out, wash out, dry out or cake up.

L. B. LAWSON, farmer near Crowley, La., (right) gets neighborly, dependable delivery of Advanced Custom-Made Havoline Motor Oil from Texaco Consignee M. A. Bergeron. Havoline cleans as it lubricates, gives added power, longer engine life and more gasoline mileage.

IN TOWN OR ON THE HIGHWAY, in all 48 states, you'll find Texaco Dealers with Texaco Sky Chief Su-preme gasoline, supercharged with Petrox for more power, more miles, more engine life . . . famous Texaco Fire Chief gasoline at the *regular* price . . . Marfak lubricant and Havoline Motor Oil.

On farm and highway it pays to use

TEXACO PRODUCTS

Texaco Products are also distributed in Canada, Latin America, and Africa.

TUNE IN...METROPOLITAN OPERA radio broadcasts every Saturday afternoon, ABC.

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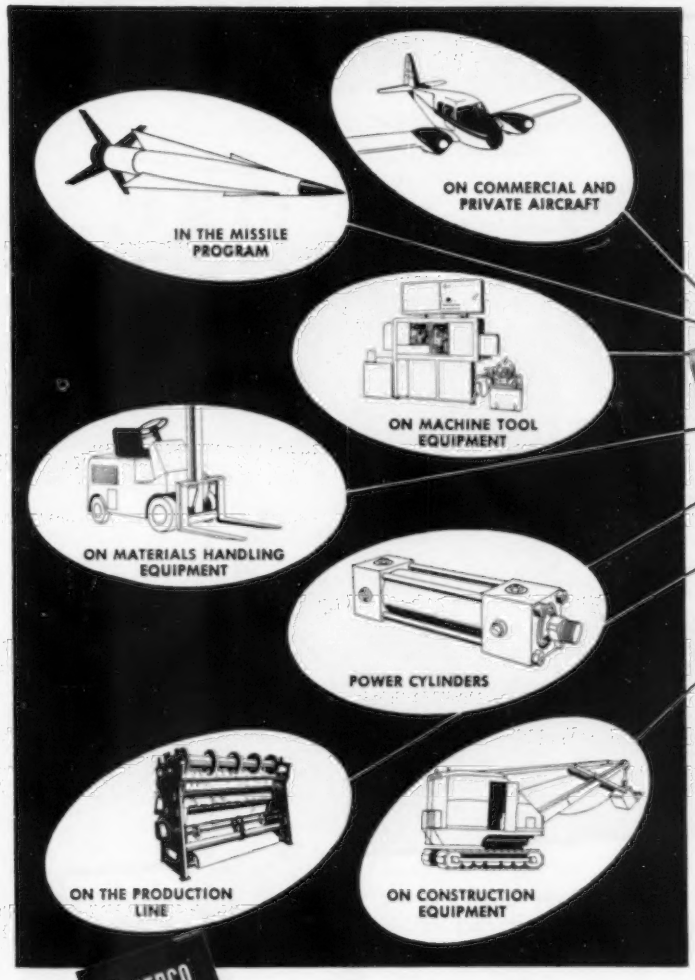
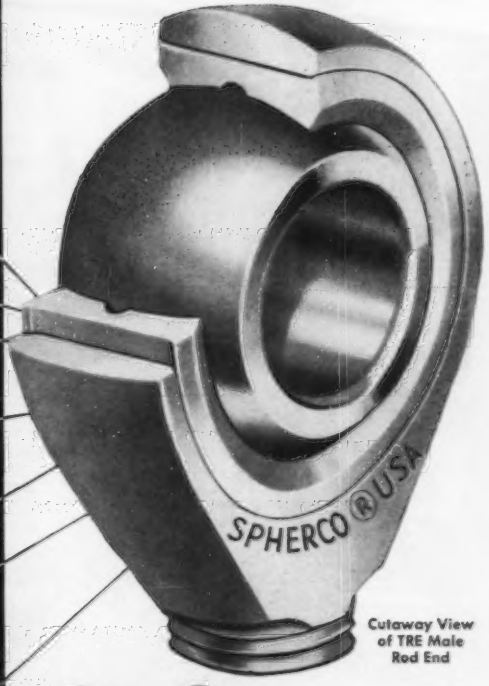
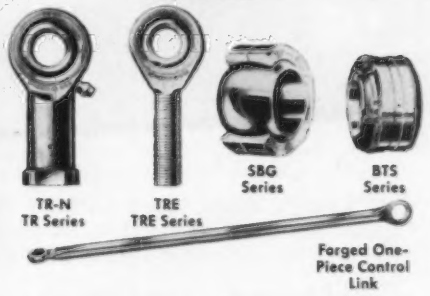
SPHERCO® Spherical Bearings and Rod Ends

FEATURING SOLID RACE DESIGN FOR OUTSTANDING PERFORMANCE!





Cutaway View of TRE Male Rod End



TR-N TR Series | TRE TRE Series | SBG Series | BTS Series

Forged One-Piece Control Link

Write today for your copy of Bulletin 257.

Wherever you find the trademark SPHERCO on a spherical bearing or rod end, you can be certain that here is engineering ahead of the field . . . quality control exercised with the finest care . . . supplier-customer engineering co-operation that solves problems before they arise . . . modern production facilities that assure quality in quantity to meet rigid customer schedules. SPHERCO Bearings and Rod Ends are available in a wide range of designs, bore diameters, selection of materials and thread sizes.

If you have a special spherical bearing problem, refer it with confidence to a SPHERCO sales engineer.

SPHERCO
BEARINGS & ROD ENDS

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For more facts circle No. 19 on reply card

BLOOD BROTHERS Universal Joints

"get the power through" to make our highways come sooner . . .

It's a rough, tough, shock-and-strain life for the average 'dozer and loader. But machines like these are ready for it. Part by part, they've had long life engineered right in from the start.

Blood Brothers Universal Joints, for example, are one of the rugged, dependable components you'll find . . . selected for their field-proved ability to withstand punishment.

On these machines—and many other kinds of road-building equipment—Blood Brothers Universal Joints "get the power through" dependably. It's one of their vital functions to help make our highways come sooner.

If you build heavy-duty equipment, write for Bulletin 557—or call on our engineers for suggestions.

ROCKWELL SPRING AND AXLE CO.

Blood Brothers Machine Division

ALLEGAN, MICHIGAN

UNIVERSAL JOINTS AND DRIVE LINE ASSEMBLIES

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For more facts circle No. 20 on reply card

Agricultural Engineering

March, 1958
Number 3
Volume 39

James Basselman, *Editor*

ASAE Motion Picture Project

FOLLOWING is a summary of a progress report of the ASAE Motion Picture Production Committee, made by L. W. Hurlbut, chairman, during the Winter Meeting in Chicago, in which he traced the activities of the Committee from its beginning and revealed latest developments and future plans for the Society's motion picture project.

The report emphasized that the first function of the Production Committee, following its formation in December 1956, was to solicit comments and suggestions from individual members in order to determine wants and needs for a movie on agricultural engineering. The Committee studied all action taken since the project began, summarized its findings and submitted them for comments and suggestions to samples of Society membership through ASAE Division representatives. After careful consideration of comments received, the Committee felt that the primary purpose "to interest young people in the challenges, opportunities, and rewards in agricultural engineering," and the objective "to help increase the supply of qualified agricultural engineers to meet the increasing need for them in research, development, production, management and education," met the approval of those who responded.

Revealing the financial status of the project, Mr. Hurlbut explained that the Council of ASAE, shortly after the Motion Picture Operating Committee was formed, budgeted $3,000 for the development of a story treatment, which has been purchased. Funds received from a drive for contributions in 1956 total $6,549.63, from which no expenditures have been made.

The Committee learned of an arrangement whereby the Motion Picture Service of the U.S. Department of Agriculture may cooperate with certain non-profit organizations in the production of films where mutual interests are being served. In order to qualify for such an agreement, it is necessary to find a co-sponsor within the U.S. Department of Agriculture. While exploring the possibilities of such an agreement the Committee found that several USDA organizations recognized a need and were interested in co-sponsoring a movie dealing with agricultural engineering. Members of the Committee met with representatives of the Motion Picture Service in Washington, D.C., and reported that the joint sponsorship would offer added advantages through provision of:

(a) an established film distribution service to provide extensive coverage
(b) distribution centers accessible to ASAE members and others in all states
(c) a listing in the film promotional literature of the U.S. Department of Agriculture
(d) authenticity and prestige
(e) facilities for film maintenance, cleaning and storage.

After further consideration of the existing story treatment along with the comments received from ASAE members, the Committee recommended:

1 That the story treatment be given a major revision in line with general interpretation of what the membership wants in an ASAE movie.

2 That the Council of ASAE develop a cooperative agreement with the Motion Picture Service of the U.S. Department of Agriculture for the preparation of a script and shooting sequence for review prior to undertaking production work.

The report indicated that such an agreement would provide for the production of a 16-mm, color motion picture, with sound, not to exceed 13½ minutes in length. The Motion Picture Service would supervise production of the film, supply technical advice for shooting and production, and exercise full responsibility for making the picture. It would prepare and distribute prints of the film to the general public through the facilities of its film libraries and television contacts.

The Society would supply a technical advisory committee made up of ASAE members representing college agricultural engineering departments, industry and the U.S. Department of Agriculture. This committee would serve under the overall supervision of the ASAE Motion Picture Production Committee and would provide assistance in the preparation of the script and production of the film and would review and approve outline, script, interlock and answer print. It would be the function of this advisory committee to see that the agricultural engineering story is presented with accuracy and authenticity. The Society would also be expected to pay an amount not to exceed the cost of producing the film and preparing release prints for distribution. It is anticipated that this amount will be approximately $23,000, depending on the cost estimate of producing the approved script, and including $5,000 for approximately 100 prints of the film. As indicated earlier, $6,549.63 of this amount has already been contributed.

Subsequently, the Council of ASAE voted to accept the Committee's recommendations and that a technical advisory committee be appointed to work directly with U.S. Department of Agriculture in planning the picture. It has also authorized that $2,000 of the special motion picture fund be budgeted to produce script and shooting site sequence. The time table calls for a shooting script by the time the Council meets again during the Annual Meeting in June. The Motion Picture Production Committee invites ASAE members not already contacted to send any ideas or comments to L. W. Hurlbut, chairman, in order that this will be a completely representative film incorporating the best ideas advanced by the membership.

Trends in Ball Bearing Design for Farm Machinery

R. S. Howe, Jr.
G. H. Raley

THERE appear to be four major trends in the design of ball bearings for farm machinery. One trend is all-inclusive and upon it all the other three depend. It is the application of precision ball bearings to farm equipment. Dependent on this are the three other trends: prelubrication, tight integral seals, and housed or "packaged" ball bearing units.

Precision ball bearings have been used for many years in the transmissions and gearbox drives of farm machinery as well as in those of automobiles, trucks, and tractors. But the application of equal-quality ball bearing units to the shafts which motivate the wide variety of implements is a relatively new science, hardly more than ten years old. Problems of sealing, lubrication, alignment, and protection from wrap, peculiar to this equipment, present a challenge to ball-bearing manufacturers in these new applications.

Some of the simpler and less costly machinery such as tillage tools are currently being equipped with permanently supersealed ball bearings. Then, too, new types of farm machinery requiring ball bearings are being introduced. A recent example of this is the hay crusher which, due to rugged operating conditions, requires the use of sealed high-capacity bearing units in order to obtain satisfactory service life.

There are also more and more conversions from sleeve to ball bearings on standard farm machinery. Some examples of this include the crankpin on hay balers, tine bars on hay rakes, and elevators of combines. This paper will discuss some problems of design and development for such applications.

A major design essential for a successful ball bearing application is lubrication. Not the crude axle-grease type of lubrication to stop squeals, but lubrication of a very special sort. Ball bearing manufacturers spend thousands of dollars testing greases in an effort to find that special sort.

In a ball bearing, which depends on rolling friction instead of sliding friction, lubrication does not carry the load but does perform certain secondary functions. Because these functions are not limited to vital specific needs, very little lubricant is consumed as a result of bearing rotation (Fig. 1). Most of the grease is inactive which means that only a slight amount of it rotates or is agitated by bearing rotation. Thus little heat is developed.

There is some friction between balls and retainer pockets but negligible lubrication is absorbed there. Thus a small cavity of grease in a securely sealed bearing is adequate for lubricating the bearing for a long time.

In their constant search for better greases, ball-bearing manufacturers subject each new grease to a series of standard tests which determine its suitability for a ball-bearing lubricant. One of the most important questions about grease is: "Will it maintain chemical stability during long idle periods?" The answer is found by the oxidation bomb test which subjects grease samples statically to oxidation at an accelerated rate under controlled temperature and pressure. Another important quality is cleanliness of the grease which is measured by a dirt count. This is determined by examining a thin film of grease on a porcelain plate under binoculars.

Consistency of grease is important, too. It may be defined as a measure of the resistance of a grease to permanent change in shape. The consistency rating according to the ASTM method is measured by the depth to which a cone of known weight and shape will penetrate the grease in a given time at a given temperature. This rating measured before and after "working" should change only to a slightly softer value. Working is a test which aims to duplicate running by milling and straining the material.

Dropping point, which is the melting temperature, and bleeding, which is the tendency to separate at various temperatures, are other tests run on greases selected for use in ball bearings. Most general-purpose greases are satisfactory for operation at temperatures from −20F to 180F.

New greases must pass a battery of tests which include the foregoing together with others. Samples of routine production shipments of grease are checked by these tests to

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The authors — R. S. Howe, Jr. and G. H. Raley — are, respectively, application engineer and engineering manager, standards and procedures, The Fafnir Bearing Co.

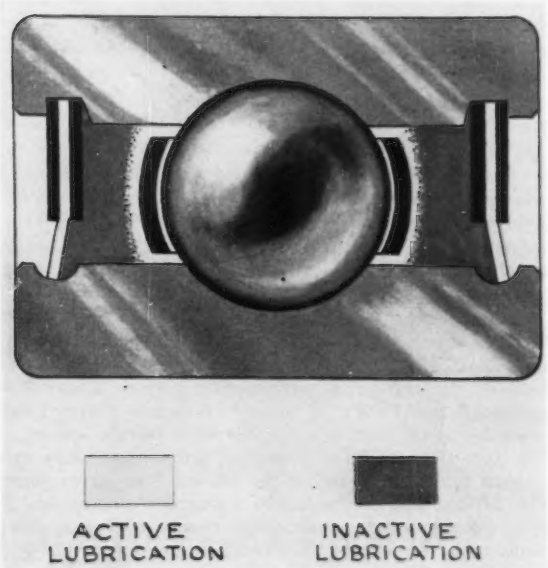

Fig. 1 The light area around the ball and retainer of this bearing shows active lubrication, while the dark area indicates inactive lubrication

Facts concerning lubricants, prelubrication, seals and housed units are presented as supporting evidence that the grease gun will become outmoded as tomorrow's bearings develop

insure that quality of lots is maintained even though that particular brand and number of grease has been placed on the acceptable lists. Each lot is thoroughly filtered before use for prelubricating ball bearings.

One interesting controversy in the ball bearing lubricant field concerns water-soluble greases vs. water-resistant greases.

A water-soluble grease, as the name implies, is one which will absorb water up to a certain saturation point. At absorption values below this point the grease-water combination will form an emulsion which will provide satisfactory lubrication. A non-soluble or so-called water-resistant grease, on the other hand, resists moisture and therefore will allow droplets to collect which could cause rust. Beyond the saturation point, a water-soluble grease could wash out completely thus causing failure. However, on the basis of our experience, we believe that, if the bearing seals allow penetration of moisture beyond the saturation point, they are not affective to resist dirt and other contamination so prevalent in farm-machinery applications. Other advantages of water-soluble greases are that after emulsifying they will return to their original state after a drying cycle, and they generally have better life characteristics than the water-resistant greases.

Where a bearing is mounted on a vertical shaft so that a pool of water could collect at the top of the bearing, thus making sealing difficult, a water-resistant grease may be used to advantage.

Bearings "Lubricated for Life"

The question might be asked as to just what is meant by the term "lubricated for life." Does it mean the life of the lubricant, the life of seals, or the theoretical life? To us, it simply means how long a bearing will last before normal fatigue failure or induced failure from outside causes is reached. The life of bearings is as variable as the equipment on which they are used and the service conditions under which they operate. One of the major causes of premature bearing failure is improper relubricating practice. Obviously it is necessary for bearing manufacturers to straddle the fence when it comes to endorsing prelubrication or relubrication, but in discussing the trend toward prelubrication of ball bearings for farm machinery, mention will be made of at least five reasons why bearings designed for relubrication are taking a back seat, as follows: *(a)* Grease guns filled with dirty or incorrect grease force contaminants into the bearings through dirty grease fittings which are seldom thoroughly cleaned before relubrication. *(b)* Excess grease purges through the seals and forms an area (Fig. 2) where dust and dirt cling and build up around the bearing. *(c)* Some grease may squeeze between the outer ring and the housing, thus providing lubrication for a potential case of outer ring spinning, or, in effect, the outer ring and housing acting as a plain bearing. This can seriously wear away the housing bore and outer ring outside

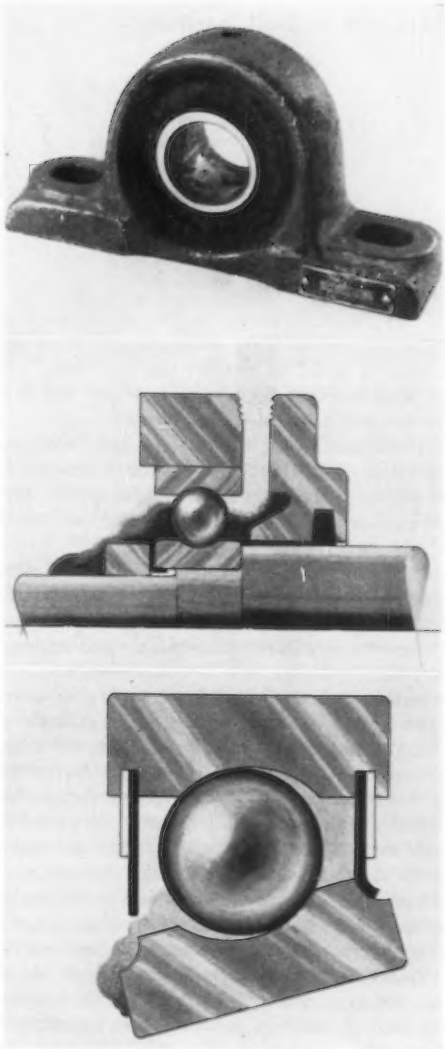

Fig. 2 *(Top)* Excess grease purges through the bearing seals to form an area where dust and dirt cling and build up around the seals. • Fig. 3 *(Center)* This view shows how new smooth grease will often slide over a hard mixture of old grease and contamination. • Fig. 4 *(Bottom)* An exaggerated misaligned condition of a bearing showing grease leaking under the seal

diameter so that the fit becomes excessively loose. A bearing which becomes packed tightly with dirt will of course accelerate this condition. *(d)* New grease forced into the bearing usually does not purge the old grease and accumulated contamination. Rather the new smooth grease will often slide over the harder consistency mixture of old grease and contamination and purge out through the seals (Fig. 3). In such extreme cases relubrication is absolutely worthless. *(e)* Greases used to relubricate ball bearings on the farm probably are incapable of passing half the tests which are considered important in the success of a ball-bearing lubricant. In other words, there is no guarantee that the same type of thoroughly tested and filtered ball-bearing grease used in prelubricating the bearing at the factory will be used in relubricating it at the farm.

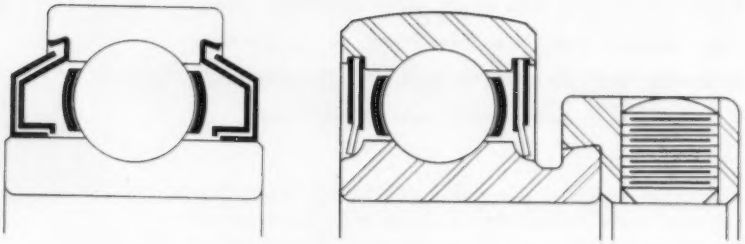

Fig. 5 *(Left)* Bearing with frictionless labyrinth type of seal. • Fig. 6 *(Right)* Contact seal designed for minimum width

The foregoing arguments against relubrication can be used in a positive sense to emphasize the need for prelubrication. In order to preserve the lubrication within a bearing, it is necessary to have a dust-tight and dirt-tight seal and one which will also resist moisture.

With reference to the third design trend mentioned at the beginning of this paper, the latest indication is that integral sealing of bearings is fast replacing old outmoded methods because it achieves a more compact and economical design.

Early studies of seal designs were made, for the most part, with specially critical attention toward minimizing friction. The torque drag of present-day heavy multilip contact seals was at one time considered unacceptable and improper for good ball bearing design. It is now conceded that the torque of such seals in their application is generally small in relation to the power used to rotate the shaft. An example of this can be cited from the assembly of a gang of disks mounted on triple-lip sealed ball bearings. Although the unmounted bearing rotated in one's hand may feel as though the drag is intolerable, the gang of disks mounted on these bearings will rotate smoothly and easily with a light hand push at the edge of the disk and will coast gradually to a stop.

With reference to basic considerations in seal design, the first are those which relate directly to the bearing and not to the seal configuration itself. One of these concerns the running eccentricities of sealing surfaces which should be minimum for most efficient sealing. Precision bearings and precision seals go hand in hand. To cite an extreme case, if the inner ring eccentricity of a ball bearing exceeds the interference contact of the seal on that inner ring, it is evident that at certain points on the inner ring there will be no contact. A large eccentricity tolerance range results in a wide variety of seal performance between bearings of a given lot and is not in keeping with the policies of good quality control.

Another consideration is the internal clearance within a bearing. Greater internal clearance will have the same effect as excessive radial eccentricity. In addition, under misaligned conditions the contact or pressure of the contact may be relieved to the point of ineffectiveness (Fig. 4).

Finish of the surface on which the seal rides is important, of course, and will affect performance of the seal. At the same time, unless internal clearance and eccentricities are carefully controlled, there is little significance in having an especially smooth finish.

The precision quality of a bearing, therefore, is important in designing a successful seal.

Of no less importance, of course, is the design of the seal itself. Some of the most important seal characteristics are: *(a)* High tear strength in the seal material because of the severe abrasive dirt conditions which often prevail, *(b)* stiffness and flexibility which will affect the contact pressure of a seal and ability to "follow up" on the contact surface, and *(c)* accurate dimensional control of thickness, bore, and outside diameter of the sealing member. In that respect, these tolerances are held to within a few thousandths and each lot is checked for correct figures. *(d)* Storage stability, especially under humid conditions, and resistance to solvents. It is surprising to learn what certain farm fluids can do to a bearing seal. Not only physical breakdown but also dimensional stability are important under these conditions. *(e)* Compatibility with greases is also important. Dimensional stability must be preserved and physical deterioration must not take place in the presence of approved greases at all temperatures for which they have been approved.

The foregoing explains some very important characteristics of efficient ball bearing seals. Several configurations of efficient seals will be discussed briefly in the following paragraphs:

One is the frictionless labyrinth-type seal (Fig. 5). This consists of two metal caps or stampings, one of which rotates with very close clearance external to the stationary member. This seal attains peak effectiveness at speeds where centrifugal action of the slinger aids in keeping dirt and dust away from the bearing. Although this seal has been effectively used in farm machinery, it is now becoming less prevalent and is being gradually replaced by contact type seals which are varied in design.

Fig. 6 incorporates a contact seal on each side of the bearing which has been designed for minimum width.

A more elaborate contact seal features a heavy interference flare-out construction. This seal (Fig. 7) with its relatively heavier contact imposes a speed-limiting factor in the bearing, not generally reached in farm machinery. These seals are oil impregnated and derive some lubrication from this source as well as from the grease within the bearing.

It is true of course that this seal has a higher initial torque than the aforementoned style, but nevertheless it is

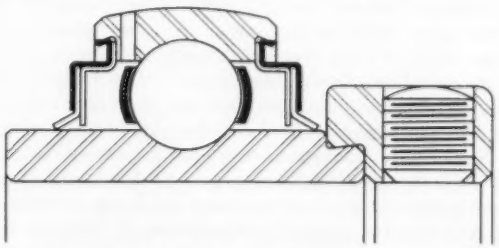

Fig. 7 Contact seal with heavy interference flare-out construction

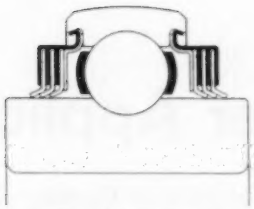

Fig. 8 The triple-lip bearing seal

small in relation to the input torque of its typical application. In fact, these bearings are spun at the factory on a 1/10-hp motor with no problems of overload.

The triple-lip seal (Fig. 8) represents the ultimate in built-in sealing efficiency. It has the flare-out feature and incorporates spacers of specified thickness to keep the seal lips properly spaced on the inner ring outside diameter. The speed of bearings using this seal is definitely limited but is quite a bit higher than those encountered in disk implements for which it was primarily designed. In fact, there are successful applications which reach 800 to 1,000 rpm, and in a small size bearing, of about ½-in bore, we have successful applications of 1800 rpm. The temperature at the seal contact may exceed 200F during the first hour at speeds of about 600 fpm. After this run-in period the temperature will level off to about 150 F. The grease which is used with this bearing has been proven to be the optimum lubricant for keeping the seal in good condition during the high-temperature cycle.

It should be noted that the flare-out seal design allows great versatility in manufacture. In the same bearing, for example, a single, double, or triple seal can be incorporated with a surprising amount of ease and a minimum of new parts. This factor allows almost any sealing problem to be solved.

In order to make any seal-development program worth while it is necessary to test effectively each new idea that comes off the boards. Of course, in the final analysis the field test is the most valuable, but it is also long and costly. Therefore, we try in our laboratory to subject our sealed bearings to tortures far more severe than any which might be encountered in the field.

In a test rig which we simply call a dust box (Fig. 9), materials such as emery dust and a very penetrating type of coal dust are used to obtain quicker test results on the effectiveness of a particular seal design.

The actual number of hours service in a dust or emery box may not correlate too closely with hours in the field because of the amount of idle time between periods of field use and other factors, but its real value is in being able to compare different seal configurations. There have been cases where one seal design has shown up better than another in dust-box testing but in the field has worked the opposite way. Usually the reason is due not to dirt directly but to unusual wrap of stalks or fibers or moisture problems, both of which are important in the farm machinery field.

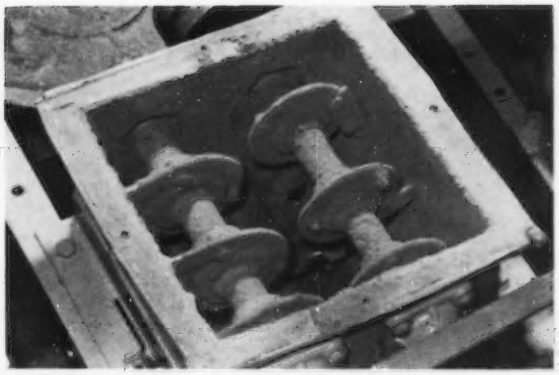

Fig. 9 Dust box for testing the effectiveness of bearing seals

The fourth design trend mentioned at the beginning of this paper was housed units or special bearing "packages". Packaged bearings fall into two categories: the conventional cast iron type and the newer pressed-metal stamping, each of which may be aligning or non-aligning.

A cast iron self-aligning housing (Fig. 10) features an accurately machined spherical seat which houses the spherically ground bearing outer ring. Both are carefully matched to produce an accurate fit which is useful in preventing outer-ring spinning under vibration and unbalanced loading which are important factors in farm machinery applications.

Caution must be taken especially where vibration or shock loading is present that the housing is never more than about 0.002 in. larger than the bearing outside diameter because the outer ring is apt to fracture under hoop stresses developed through lack of full support around the circumference.

The pressed metal housing (Fig. 11) is composed of two similar halves bolted together. Due to the wider tolerance range required in manufacturing, the fit of such a design must be either tight or loose after tightening of bolts. The best designs have a tight fit after bolt tightening. Since a stamping will expand, the interference fit, for the most part, is absorbed by the stamping so that no harmful preloading is imposed on the bearing.

There are certain applications where the pressed-metal

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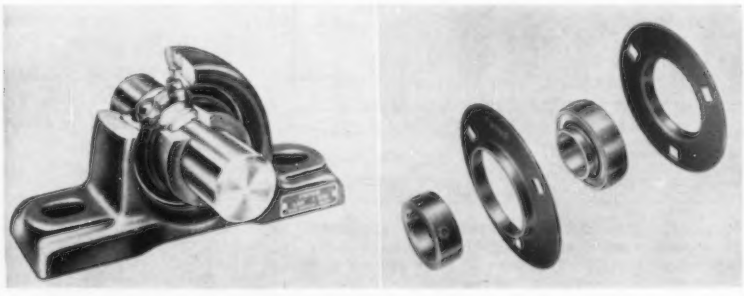

Fig. 10 *(Left)* Ball bearing pillow block featuring a one-piece cast iron self-aligning housing. • Fig. 11 *(Right)* Pressed metal housing of two identical halves

Comparing Efficiencies in Irrigation Water Application

B. R. Somerhalder
Assoc. Member ASAE

Efficiency in water application becomes more important as demands on irrigation water increase. This article describes a comparison study of water requirements between sprinkler and surface irrigation systems

WATER application efficiency has been defined by the Committee on Irrigation of the American Society of Agricultural Engineers (2)* as the percentage of the water applied that can be accounted for as increase in soil moisture in the soil occupied by the principal rooting system of the crop. Water application efficiency is a dimensionless physical quantity that is independent of crop response to irrigation.

The first detailed field measurements of irrigation efficiency known to Israelsen (9) were made by Beckett, *et al*, (1) of the California Experiment Station. They field tested furrow and spray methods of water application in orchards. Low water application efficiencies, caused primarily by the irrigation practices used, were found on a number of Utah farms by Israelsen (10).

Tests of the sprinkler method in Kansas (12) indicated that the application efficiency increased as the irrigation interval and quantity of water applied was increased within limits of the water holding capacity of the root zone. Sprinkler tests in Arizona (13) showed that losses due to evaporation of the spray on a hot day, and to wind drift, can be as much as 30 percent of the water applied. Sprinkler irrigated farms in the Columbia Basin Project (16) were found to require less water than surface irrigated farms for the same level of production. Later studies for the same project (17) confirmed the earlier results.

The importance of efficient management of water supplies for irrigation was emphasized by Clyde (3). By increasing the irrigation efficiency in the Western states to 50 percent, existing water supplies would be supplemented by approximately 25 million acre-feet without the construction of a single reservoir, diversion, or main canal.

The test area used for studying application efficiencies of sprinkler and surface irrigation was located on the University of Nebraska, North Platte Experiment Station. A component of Ranger Alfalfa (A-110) was grown on all of the plots throughout the period of this study. The soil was a Bridgeport fine sandy loam with an average surface slope of approximately one percent. The water table on this area was 12 to 15 ft below the surface. Alfalfa production on an adjacent non-irrigated area indicated that ground water furnished a source of moisture when the available water in the upper root zone was depleted.

Laboratory determinations of moisture capacities at one-third atmosphere tension (considered field capacity) and at 15 atmospheres (considered as permanent wilting percentage) were 18.2 percent and 9.5 percent, respectively. These moisture percentages represented about 2.8 in. and 1.4 in. of water per ft of soil. The difference, 1.4 in. per ft of soil, was considered to be water readily available for use by plants.

The basic water intake rate for this soil was 0.5 to 0.6 in. per hr. The apparent specific gravity of the soil was in the range of 1.2 to 1.3.

The plots were 500 ft in length by 60 ft in width surrounded by an earth border dike four-tenths to five-tenths ft in height. All plots were corrugated on a 30-in. spacing parallel to the 500-ft dimension to facilitate water control.

A unique feature of this test area was a source of water piped from the Platte Valley Public Power and Irrigation District penstock which connected to a lake at an elevation about 200 ft above the plots. Water under pressure was sup-

*Numbers in parentheses refer to the appended references.

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The author — B. R. SOMERHALDER — is assistant agricultural engineer, agricultural engineering dept., University of Nebraska.

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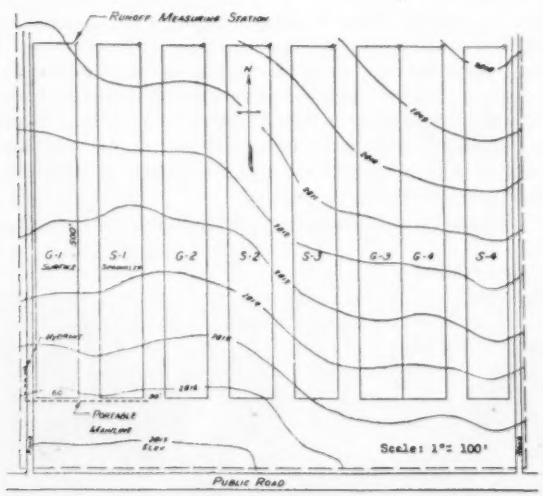

Fig. 1 The area used for comparing the application efficiency of the sprinkler and surface irrigation of alfalfa at the North Platte Experiment Station. The contour lines are on a vertical interval of one foot

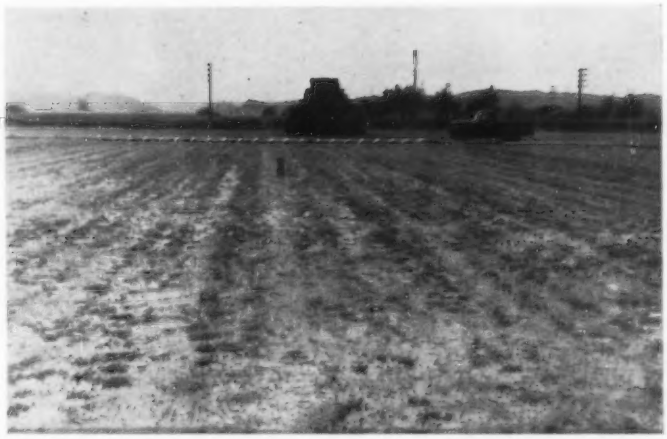

Fig. 2 Water was delivered to surface irrigated plots through gated pipe. A complete sheet of water covered the plot

plied on demand. The rate of flow and the pressure were controlled with a gate valve in the supply line.

Experimental Procedure

The experimental area was divided into eight plots, Fig. 1. Four plots were irrigated with sprinklers. The other four plots were surface irrigated using gated pipe. The irrigation water applied to each plot was measured by a recording meter. Runoff from each plot was measured by a 3-in. Parshall flume equipped with a water stage recorder. A recording rain gage was located on the test area to record natural precipitation.

The irrigation was planned to maintain moisture at the same level on all of the plots. The hypotheses back of this plan were: *(a)* If moisture is equally available for plant use on all plots alfalfa yields should be the same; and, *(b)* The difference, if any, in the irrigation requirements to maintain equal moisture levels are caused by the difference in water application efficiency between the two methods.

Plots were irrigated in pairs, a sprinkler irrigated plot and a surface irrigated plot received an irrigation simultaneously, or as nearly so as the time and mechanics of operation permitted. Water was applied to a sprinkled plot with part circle sprinklers spaced at 40-ft intervals on the lateral placed along the side of the plot. One-half of the total irrigation requirement was applied from each side of the plot. The time required to irrigate a sprinkled plot was approximately twice that required to irrigate a surface irrigated plot. Wind velocities as high as 15 to 20 mph were encountered at times during an irrigation. The sprinkler irrigation was not interrupted unless the wind velocity and direction would carry substantial amounts of the water beyond the test plot.

Surface irrigated plots received water from a gated pipe. The stream size delivered to each plot was controlled so that the initial stream completely covered the plot in one-fourth to one-fifth of the required total irrigation time. When excess surface water began to escape, the size of the irrigation stream was reduced to provide the quantity needed to maintain good coverage on the plot without excessive runoff. The mean runoff from surface irrigated plots during the 3-year period was 8 percent of the total quantity applied.

Irrigation water was applied after each harvest. The harvest schedule permitted four irrigations during each growing season. The principal reason for applying water only subsequent to harvest was to minimize the interference of plant growth with irrigation and soil sampling operations. Intervals between irrigations were approximately 30 days.

The top 6 ft of soil was considered the working depth occupied by the principal rooting system of alfalfa. It is estimated that more than 95 percent of the alfalfa roots were in this zone (8)(15), even though root penetration was much deeper. Sections of roots appeared in soil samples drawn from a depth of 15 ft within the test area. Soil moisture extraction patterns obtained by Shockley and others (7, 11, 14) from crops under irrigation indicated that, if moisture was readily available, plants extracted their water requirements in approximately a 4-3-2-1 ratio from the top to the

Fig. 3 Part-circle sprinklers applied water to sprinkled plots. One-half of a required irrigation was applied from each side of a plot

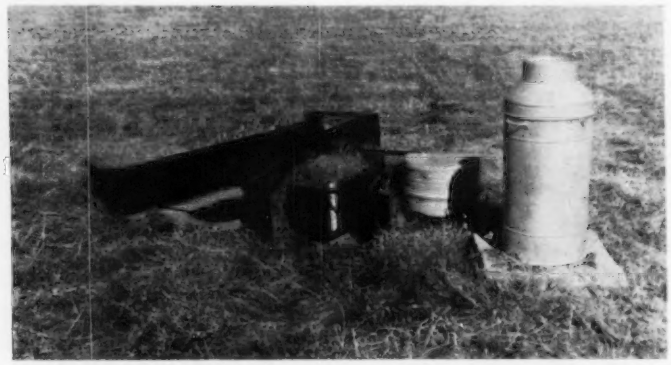

Fig. 4 Parshall flumes, water stage recorder well, and recording rain gage at runoff measuring station on plot S-3. When measuring water application efficiency the runoff as well as the water applied must be measured

. . . Irrigation Efficiency

lower one-quarter of their root zone. Although no effort was made to check the moisture extraction pattern on this area, it was observed on the basis of before-irrigation soil moisture samples that the greatest change in moisture occurred in the upper 4 ft of soil.

The irrigation requirement (shown in Table 1 as water applied to plots) was calculated on the basis of soil samples

TABLE 1. WATER APPLIED, WATER ADDED TO ROOT ZONE, AND APPLICATION EFFICIENCIES FOR SPRINKLER AND SURFACE IRRIGATION ON ALFALFA PLOTS AT THE NORTH PLATTE EXPERIMENT STATION.

Year	Water applied to plots, in.	Water added to root zone, in.	Application efficiency, percent
	Sprinkler irrigated plots		
1952	28.4	24.0	84
1953	29.2	24.1	82
1954	25.7	22.0	86
Mean	27.8*	23.4†	84
	Surface irrigated plots		
1952	32.5	24.5	75
1953	34.6	23.4	68
1954	29.6	21.7	73
Mean	32.2*	23.2†	72

*Difference between methods statistically significant at 1 percent level.
†Difference between methods not statistically significant.

taken with a Viehmeyer tube in 1-ft increments to a depth of 6 ft, one or two days before an irrigation (the soil samples were oven dried to determine their moisture percentage). The moisture percentage before irrigation was subtracted from the moisture percentage at one-third atmosphere tension. The irrigation requirement was then computed on the basis of this difference and an assumed application efficiency of 80 percent. The amount of water applied by an irrigation was the sum of the requirements determined for each foot of soil to a depth of 6 ft. This procedure can be expressed by the equation:

$$d=\sum_{1\text{ ft}}^{6\text{ ft}}[(P_{fc}-P_{w1})/(100\times 0.8)]\,A_s\,12\text{ in.}$$

Where d = Depth of water to be applied, inches
P_{fc} = Soil moisture percentage at one-third atmosphere tension
P_{w1} = Soil moisture percentage before irrigation
A_s = Apparent specific gravity of soil

In order to measure the change in moisture resulting from irrigation, soil moisture samples were taken again approximately three days after completion of an irrigation. The gain in soil moisture represented most of the irrigation water that was stored in the root zone. Another part was the daily use of water by the crop in the period between before-irrigation and after-irrigation moisture samples. Fuhriman (5) concluded that a correction factor taking into account the daily use between sampling dates should be included in computing the net water added to the root zone by an irrigation. In this work the adjustment factor was 0.15 in. per day. Soil moisture added to the root zone was calculated by using the equation:

$$d_s=\sum_{1\text{ ft}}^{6\text{ ft}}[(P_{w2}-P_{w1})/100]\,A_s\,12\text{ in.}+0.15\,n$$

where: d_s = Water stored in root zone, inches
Pw_1 = Soil moisture percentage before irrigation
Pw_2 = Soil moisture percentage after irrigation
A_s = Apparent specific gravity of soil
n = Number of days between before, and after-irrigation soil moisture samples

Water application efficiency, "E_a", was calculated by the equation:

$$E_a=(d_s/d)\ 100$$

Alfalfa yields, Table 2, were obtained by mowing a strip 30 ft in length by 38 in. in width at three locations in

TABLE 2. ALFALFA HAY PRODUCTION OBTAINED FROM IRRIGATED PLOTS AT THE NORTH PLATTE EXPERIMENT STATION. (TONS PER ACRE WITH 12 PERCENT MOISTURE.)

Plot number	Annual hay production, tons per acre 1952	1953	1954	Mean
	Sprinkler irrigated plots			
S-1	7.1	6.2	6.3	6.5
S-2	6.4	6.1	6.2	6.2
S-3	7.3	6.5	7.1	7.0
S-4	6.7	6.3	6.7	6.6
Mean	6.9	6.3	6.6	6.6*
	Surface irrigated plots			
G-1	7.0	5.9	6.0	6.3
G-2	6.8	6.2	5.9	6.3
G-3	7.5	6.7	6.5	6.9
G-4	7.0	6.7	6.5	6.7
Mean	7.1	6.4	6.2	6.6*

*No difference between methods of irrigation.

each plot at each cutting. Green forage weights were taken and moisture percentages were determined by oven-drying green forage samples. Data thus obtained was used to compute alfalfa production in tons of 12 percent moisture hay per acre.

Discussion of Results

The amount of irrigation water applied each year, Table 1, was the sum of four different water applications during a cropping season. The depth of water applied during each of the irrigations ranged from 6 to 10 in. There was close agreement in the quantity of water added to the root zone for both methods of water application. A mean annual depth of 23.2 in. of water was placed in the root zone by the surface method as compared to 23.4 in. of water placed there by the sprinkler method. The difference of 0.2 in. was not statistically significant. This indicated that the two methods of irrigation provided the same moisture conditions for plant growth. Irrigation requirements for adding this quantity of water to the root zone were 32.2 in. and 27.8 in., respectively, for surface and sprinkler irrigation. Surface irrigation required 4.8 in. more water annually than the sprinkler method to accomplish the same result. The difference in water requirements for the two methods of irrigation was statistically significant at the one percent level. Mean water application efficiencies as indicated by these data were 84 percent for the sprinkler method and 72 percent for the surface method. The difference of 12 percent in application efficiency was largely due to larger amount of runoff from the surface irrigated plots.

Alfalfa hay yields, Table 2, were additional evidence that equal moisture levels were provided by the two methods of water application. Even though there were small differences in mean production for the individual years, the mean annual production for both methods of irrigation through the three-year span was 6.6 tons of 12 percent moisture hay per acre. This indicated that the method of water application had no effect upon the yield of hay.

A factor contributing to the relatively high water application efficiency obtained on the plots in this test was the fact that relatively heavy water applications (6 to 10 in.) were used for each irrigation. Fortier and Beckett (4) recorded uniformly heavy evaporation loss from wet surfaces, especially during the first three days after an irrigation. The importance of surface evaporation losses subsequent to irrigation can be minimized by applying the quantity of water required to restore soil moisture in the root zone to field capacity at the maximum irrigation interval consistent with the character of the soil and the rooting habits of the crop irrigated.

The results obtained in this study are applicable to well designed sprinkler and surface irrigation systems which are managed carefully. Each system was operated in accordance with excellent irrigation management practices on an area where there was a choice between the sprinkler and surface methods of irrigation. Even under these carefully selected conditions, application efficiency is only one of a number of factors that should be considered when a choice of irrigation system is made (6).

Summary

A study of water application efficiencies for sprinkler and surface irrigation of alfalfa on plots at the University of Nebraska, North Platte Experiment Station, during 1952, 1953, and 1954, produced the following results:

(a) The mean annual irrigation requirements to produce 6.6 tons of alfalfa hay per acre were 27.8 in. and 32.2 in. of water for sprinkler and surface irrigation, respectively. Sprinkler irrigation produced the same yields as surface irrigation with one-seventh less water. Most of the difference is due to the greater amount of runoff from the surface irrigated plots.

(b) The quantity of water stored in the root zone of the alfalfa crop was not affected by the method of irrigation. Sprinkler irrigation stored 23.4 in. of water in the root zone out of a total of 27.8 in. applied compared to surface irrigation which stored 23.2 in. out of a total of 32.2 in. The mean water application efficiency on the basis of these values was 84 percent for sprinkler irrigation and 72 percent for surface irrigation.

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Fig. 1 Square bin used in the resistance of seed cotton to air flow test

Fig. 2 Close-up view showing metal transition located just below perforated floor in bin

Resistance of S

T. J. Nissing
Assoc. Member ASAE

AGRICULTURAL Engineers working with cotton production, handling and processing at one time or another need information on the resistance offered by seed cotton to air flow. Forcing air through seed cotton has been tried at the U.S. Department of Agriculture cotton ginning research laboratory, Leland, Miss., under various conditions, using both heated and unheated air, in drying machines, as well as in storage structures or bins. Results from these tests have shown that the power requirements to force air through seed cotton are by no means negligible. In an effort to determine the relationship between air movement through seed cotton and the resistance offered by the cotton, a study was developed for the purpose of obtaining accurate data that could be used to determine the power requirements of any system handling forced air through seed cotton, and to study any possible significant differences between machine-picked cotton, containing a large foreign matter and moisture content, and hand-picked cotton with low foreign matter and moisture content. A study of the possible differences in pressure as affected by seed cotton densities was also included under the test objective.

Laboratory Equipment

The square bin used for this test (Fig. 1) was constructed with 1 x 8-in. shiplap boards nailed onto a 2 x 4-in. frame. The inside of the bin was covered with asphalt roof-

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The author—T. J. NISSING—was, formerly, agricultural engineer at the USDA Cotton Ginning Laboratory, Leland, Miss., now, research associate in agricultural engineering, Louisiana State University.

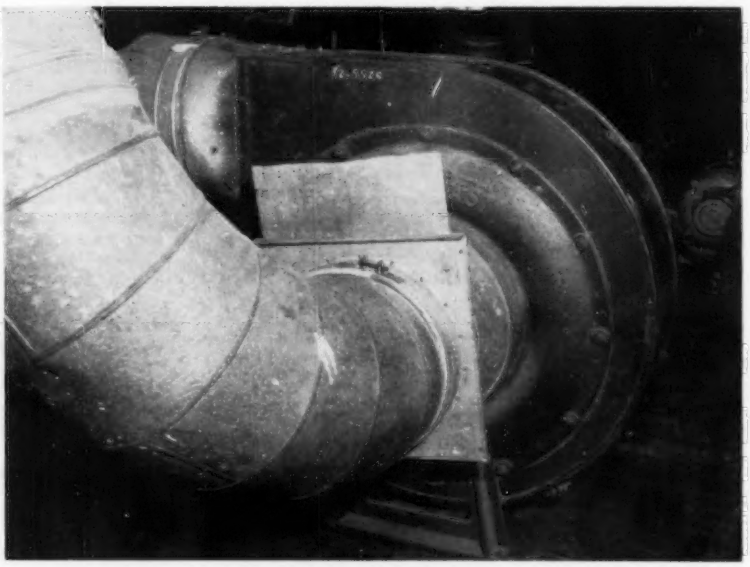

Fig. 3 Slide damper located at the fan inlet and used for controlling the air flow throughout the system

Seed Cotton to Air Flow

Study of seed cotton resistance to air flow reveals basic information necessary for proper design of storage structures

ing paper, about 50 percent overlap, making the bin practically airtight. A false floor made with screen wire cloth, having 2½ x 2½-in. mesh and 16-gage wire, was used to support the seed cotton and to establish a plenum chamber under the cotton. The perforated floor was located 18 in. above the bottom of the bin (Fig. 2). The bin was built to hold cotton up to a depth of 7 ft, with a cross-sectional area of 30.515 sq ft. The air was pulled downward through the seed cotton with a No. 40* fan powered by a 30-hp electric motor. A 16-in. diameter pipe to connect fan to plenum was chosen to keep the friction of the system to a minimum and to obtain air velocities that could be recorded with sufficient accuracy with the conventional pitot tube and water manometer. The pitot tube was placed at the center of the pipe and at approximately 10 ft from the nearest irregularity or bend in the pipe. The pipe joints were sealed with masking tape to insure against air leakages throughout the system.

The velocity pressures were recorded with a micromanometer† for a pressure range of 0.005 to 0.5 in. of water. The static pressures were recorded with the same micromanometer for pressures up to one inch and with a conventional 20-in. water manometer for pressures above one inch. The quantity of air movement through the system was controlled by a slide damper, located at the fan intake, as shown in Fig. 3. Static pressures were recorded for approach velocities of 10 to 100 fpm and at approximately 10 fpm intervals. The approach velocity was held approximately constant for each static pressure reading, regardless of load variations, such as quantity, depth and/or density of seed cotton in the bin. The micromanometer was read to the nearest 0.001 in. of water with an approximate error of ±0.002 in. To determine the accuracy of the readings taken with the micromanometer, a series of settings was marked on the slide damper and air readings were taken by randomizing the settings, without disturbing the cotton in the bin. In most instances it was possible to repeat the same reading within ±0.002 in. of water. No fluctuations were observed in the water column indicating a fairly uniform air flow through the pipe at the point where the pitot tube was located. The 20-in. manometer used for recording static pressures was read to the nearest 0.1 in. with an accuracy of ±0.1 in. of water.

The cotton lots tested were of two kinds: Machine-picked and hand-picked cotton, which provided a basis for comparison between cotton free from foreign matter and with very little moisture, and cotton with a considerable amount of foreign matter and a high moisture content. The five densities tested were obtained by weighing a sufficient amount of seed cotton so that, when placed in the bin at the various depths, it would settle to the required density. The low densities were obtained by placing the weighed lots in the bin without tramping or disturbing the cotton, just by letting it fall freely into the bin. For the higher densities, it was necessary to compact the cotton until the desired density was reached. Static and velocity pressure readings were recorded for depths ranging from 1 to 7 ft of cotton, and for densities starting as low as 6 and as high as 8 lb of

*Boardman "Super-Blast" type fan with an 8-blade 32 x 8-in. plain wheel operating at 1850 rpm.

†"A Micromanometer" by Claude K. Shedd, AGRICULTURAL ENGINEERING, Vol. 34, March, 1953.

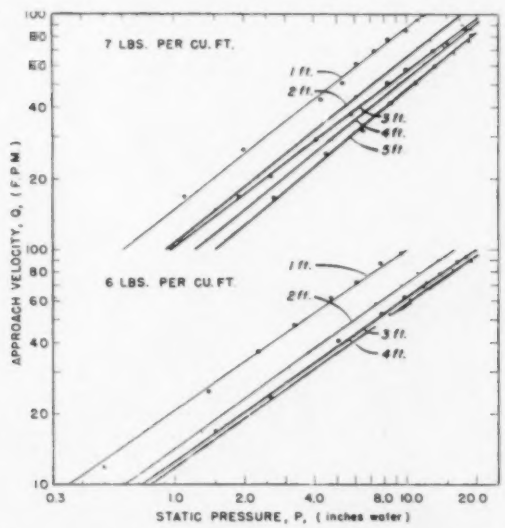

Fig. 4 Test on the resistance of seed cotton to air flow for depths of 1 to 4 and 1 to 5 ft for seed cotton densities of 6 and 7 lb per cu ft, respectively. Machine-picked cotton with 6.98 percent foreign matter and 17.3 percent moisture (wet basis)

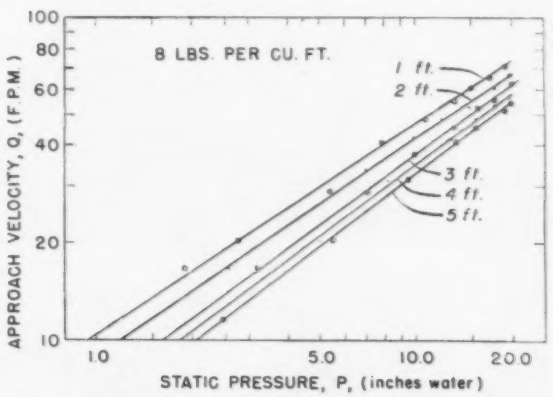

Fig. 5 Test on the resistance of seed cotton to air flow for depths of 1 to 5 ft for a seed cotton density of 8 lb per cu ft. Machine-picked cotton with 6.98 percent foreign matter and 17.3 percent moisture (wet basis)

. . . Resistance to Air Flow

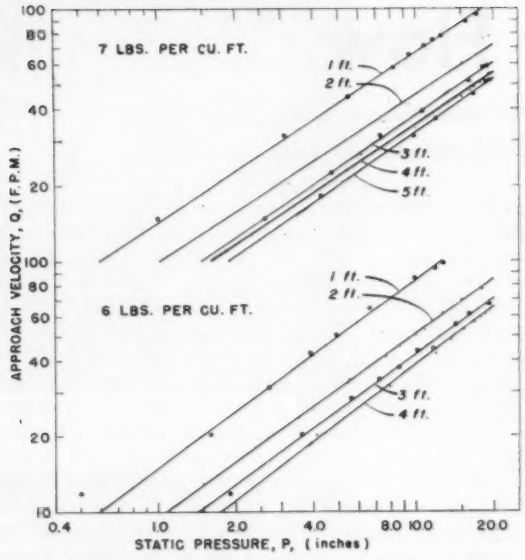

Fig. 6 Test on the resistance of seed cotton to air flow for depths of 1 to 4 and 1 to 5 ft for seed cotton densities of 6 and 7 lb per cu ft, respectively. Hand-picked cotton with 1.86 percent foreign matter and 8.68 percent moisture (wet basis)

seed cotton per cu ft. Densities lower than 6 lb were impossible to obtain since the weight of the cotton itself and the fan suction would compact the seed cotton to a greater density. Also, it was not possible to obtain a density of 8 lb with hand-picked cotton, for cotton with low moisture and foreign matter content tends to occupy a larger volume per unit weight when pressure is released.

Test Results

Density, depth, air flow and static pressures constituted the four variables of the test. Several ways of presenting these four variables in graph form were investigated, and it was found that a graph for each density showing the relationship between the air flow, in cubic feet per minute per square foot of bin area (approach velocity), and the static pressure for each foot of depth, provided the best means for analyzing and interpreting the data. It was further found that by plotting the approach velocity against static pressure on logarithmic paper, the resulting curves behaved according to the equation: $Q = aP^b$ where

Q = approach velocity in fpm = ratio of air volume in cfm to bin area in sq ft

a = constant, equal to Q when $P = 1$

b = slope

P = static pressure in inches of water

The values of a and b were calculated from the data for each straight line and are as shown in Tables 1 and 2. The equation used for calculating the average air velocity in feet per minute was $3650 \times \sqrt{\text{Velocity head (max.)}}$.

TABLE 1.—VALUES OF "a" AND "b" CALCULATED FROM DATA ON THE RESISTANCE OF SEED COTTON TO AIR FLOW. MACHINE-PICKED COTTON WITH 6.98 PERCENT FOREIGN MATTER AND 17.3 PERCENT MOISTURE (wet basis)

Density		Depth, feet 1	2	3	4	5
6 Lb per cu ft	a	20.50	14.07	12.66	11.93	——
	b	0.6860	0.7051	0.6891	0.6890	——
7 Lb per cu ft	a	14.81	10.64	10.47	8.46	7.24
	b	0.7673	0.7800	0.7302	0.7924	0.8103
8 Lb per cu ft	a	10.39	8.96	7.02	6.42	5.86
	b	0.6498	0.6706	0.7282	0.7346	0.7432

TABLE 2.—VALUES of "a" AND "b" CALCULATED FROM DATA ON THE RESISTANCE OF SEED COTTON TO AIR FLOW. HAND-PICKED COTTON WITH 1.86 PERCENT FOREIGN MATTER AND 8.68 PERCENT MOISTURE (wet basis)

Density		Depth, feet 1	2	3	4	5
6 Lb per cu ft	a	14.91	9.61	7.56	6.50	——
	b	0.7501	0.7239	0.7453	0.7687	——
7 Lb per cu ft	a	14.22	9.90	7.63	7.33	6.42
	b	0.6674	0.6563	0.6908	0.6733	0.6992

Figs. 4, 5 and 6 represent the straight line relationship (when plotted on logarithmic paper) between air flow and static pressure for machine-picked and hand-picked cotton, respectively. The horsepower requirements to force a known quantity of air through a column of seed cotton can readily be calculated from the static pressure as obtained

TABLE 3

Seed cotton density	Depth, feet 1		2		3		4		5	
	Q	P	Q	P	Q	P	Q	P	Q	P
Lb per cu ft	fpm	in.	fpm	in.	fpm	in.	fpm	in.	fpm	in.
6	11.87	0.50	12.86	1.50	11.87	1.90	20.38	4.10	--	--
	20.38	1.60	23.55	3.50	20.38	3.60	31.23	7.90	--	--
	31.23	2.70	33.40	5.50	26.40	5.60	42.42	11.90	--	--
	42.59	3.90	42.42	7.60	33.40	7.20	48.10	13.60	--	--
	50.11	4.90	45.59	8.60	37.25	8.60	52.78	15.20	--	--
	64.14	6.60	50.11	10.00	43.59	10.30	56.62	16.80	--	--
	85.00	9.90	52.78	10.70	48.60	11.70	59.63	17.90	--	--
	93.70	11.80	61.30	12.60	55.28	14.40	61.30	18.50	--	--
	96.54	12.70	68.81	15.00	61.29	16.00	62.80	19.00	--	--
	--	--	76.50	18.00	66.31	19.20	--	--	--	--
7	14.86	1.00	16.70	1.50	14.86	2.60	12.86	2.30	--	--
	31.23	3.10	20.38	3.20	22.38	4.70	26.40	6.10	18.20	4.30
	44.09	5.50	23.55	4.70	31.23	7.30	33.40	10.00	31.23	9.80
	57.79	8.20	35.41	7.50	39.08	10.70	44.09	15.10	36.24	12.00
	64.64	9.50	42.42	9.40	52.78	16.10	48.60	16.80	45.76	16.80
	70.82	10.90	51.44	12.30	55.28	17.40	50.11	17.80	50.11	18.80
	74.99	11.70	60.13	15.30	57.79	18.40	52.78	18.30	51.44	19.50
	77.33	12.60	66.31	18.20	58.96	19.00	54.12	19.30	--	--
	89.02	15.80	67.31	19.10	--	--	--	--	--	--
	94.37	17.40	--	--	--	--	--	--	--	--

Table 3 Data on the resistance of seed cotton to air flow for depths of 1 to 4 and 1 to 5 ft for seed cotton densities of 6 and 7 lb per cu ft, respectively. Hand-picked cotton with 1.86 percent foreign matter and 8.68 percent moisture (wet basis)

TABLE 4

Seed cotton density	Depth, feet 1		2		3		4		5	
	Q	P	Q	P	Q	P	Q	P	Q	P
Lb per cu ft	fpm	in.	fpm	in.	fpm	in.	fpm	in.	fpm	in.
6	11.86	0.50	11.86	0.70	23.55	2.60	11.86	1.00	--	--
	24.72	1.40	16.70	1.30	40.28	5.10	26.39	3.60	--	--
	36.24	2.30	31.23	3.10	52.78	7.80	40.92	5.70	--	--
	47.27	3.30	45.77	5.30	60.79	9.80	52.95	8.40	--	--
	60.96	4.70	57.79	7.30	68.81	11.70	61.30	10.30	--	--
	70.82	6.10	68.81	9.50	77.50	14.00	71.82	13.40	--	--
	83.51	7.70	78.34	11.10	86.85	16.60	81.01	15.90	--	--
	95.87	9.50	88.86	13.70	98.70	18.10	88.86	19.00	--	--
	--	--	93.03	14.90	--	--	--	--	--	--
7	16.70	1.10	14.86	1.50	16.70	1.90	18.70	2.30	16.70	2.70
	26.40	2.00	20.38	2.30	20.38	2.60	20.38	3.00	25.39	4.30
	42.59	4.30	28.90	3.80	28.90	4.10	28.90	4.80	31.23	6.50
	50.11	5.30	44.10	6.00	37.25	5.80	37.41	6.50	40.92	8.60
	60.30	6.10	54.12	8.10	50.11	8.30	50.11	9.50	50.11	11.00
	68.80	7.30	65.84	10.10	57.79	10.00	60.30	12.00	59.13	13.40
	77.16	8.30	70.82	11.30	69.82	13.10	70.82	14.50	65.81	15.10
	84.35	10.00	77.50	12.70	73.66	15.00	80.17	17.00	76.50	18.50
	93.70	11.20	87.52	14.80	88.36	18.60	86.85	19.00	80.17	19.30
	99.55	12.00	94.54	17.00	--	--	--	--	--	--
8	16.70	1.90	16.70	2.60	16.70	3.20	20.38	5.00	11.69	2.50
	20.38	2.80	33.40	7.00	28.90	7.10	31.23	8.20	20.38	5.50
	28.90	5.40	42.59	9.90	37.41	10.00	41.92	13.00	31.23	9.50
	40.92	7.90	48.60	12.20	45.76	13.40	48.77	15.50	40.92	13.50
	48.77	10.80	61.30	17.60	52.78	15.70	52.78	17.80	45.76	15.50
	55.26	13.40	66.98	19.70	59.13	18.80	56.62	19.50	51.44	19.00
	60.30	15.00	--	--	63.94	20.00	--	--	54.12	20.00
	66.81	17.10	--	--	--	--	--	--	--	--
	71.82	19.10	--	--	--	--	--	--	--	--

Table 4 Data on the resistance of seed cotton to air flow for depths of 1 to 4 ft for a seed cotton density of 6 lb per cu ft, and for depths of 1 to 5 ft for seed cotton densities of 7 and 8 lb per cu ft. Machine-picked cotton with 6.98 percent foreign matter and 17.3 percent moisture (wet basis)

from the graph, or by the use of the equation that has been derived for each curve. The horsepower equation follows:

$$Hp = (V \times Ps/6356) \times \text{Efficiency}$$

Hp = fan horsepower

V = volume of air, cfm

Ps = static pressure, inches of water

Since the maximum efficiency that can be expected from the most commonly used gin fans‡ is 50 percent, the horsepower calculated with the above formula should be multiplied by an efficiency factor of two, in order to determine the approximate actual horsepower required to operate the fan.

Discussion of Results

The resistance offered to the flow of air was greater for hand-picked cotton than for machine-picked cotton. Perhaps this finding can be explained by the fact that large particles of foreign matter present in machine-picked cotton, such as sticks, stems and hulls, tend to form a bridging action between the seed cotton, allowing pockets to form into which air, taking the path of least resistance, would tend to flow.

An average of all the data taken during this test shows a static pressure of 9.12 in. of water for hand-picked cotton as compared to 5.51 in. of water for machine-picked cotton. An average static pressure of 6.59 in. of water was recorded for a density of 6 lb of seed cotton per cu ft and 8.04 in. of water for a density of 7 lb. By increasing the depth of the seed cotton in the bin, greater static pressure readings were recorded for the same volumes of air forced through the seed cotton. At a depth of 5 ft of seed cotton, a point was reached whereby any additional increases in depth did not increase the static pressure readings, 5 ft being the point where the fan reached its maximum capacity to move air through the seed cotton for the existing static pressures. To handle additional air through a column of seed cotton greater than 5 ft would have required a much larger fan or the use of two fans in series, an operation that would not be feasible from an economical point of view, unless a special application would warrant its use. In such an event, consideration should be given to designing a system that would not rupture under pressures above 20 in. of water, particularly around soldered joints in the air pipes. When densities of 6 lb were used with both hand and machine-picked cotton, it was found that at a depth of 5 ft approximately ¾ ft (9 in.) settlement occurred causing very little difference between the 4 and 5-ft curves.

Considering that density is a factor that could be controlled by avoiding unnecessary tramping of the cotton in the bin, an example illustrating the difference in power requirements has been worked out as follows: To move 50 cfm of air, per square foot of bin area, through 4 ft of machine-picked cotton located in a bin having a cross-sectional area of 80 sq ft, would require 10.07 hp at a seed cotton density of 6 lb per cu ft, as compared to 11.83 hp for 7 lbs, and 20.14 hp for 8 lbs. This example illustrates the importance of maintaining the lowest possible and most uniform density attainable. By using an approach velocity of 30 fpm in the example, the horsepower requirements are reduced to 2.94 for a density of 6 lb, 3.74 for a density of 7 lb, and 6.04 for a density of 8 lb of seed cotton per cu ft, which illustrates the variations in power requirements due to the quantity of air handled.

Summary

An attempt has been made in this test to establish the relationship between air flow through seed cotton and the resistance offered by the seed cotton to such flow. The approach velocity of air has been plotted against static pressure offered by cotton for seed cotton densities of 6, 7 and 8 lb per cu ft for machine-picked cotton, and densities of 6 and 7 lb for hand-picked cotton. The amount of foreign matter and moisture present in the cotton, and the density and depth were found to definitely affect the horsepower requirements to force air through the cotton.

These data also show that the resistance of seed cotton to airflow is considerable and that engineers should carefully design such systems to provide sufficient fan capacity to

(Continued on page 165)

‡Centrifugal fans capable of delivering from 3500 to 7000 cfm at static pressures of 8 to 20 in. of water.

Back Siphonage Testing of Livestock Watering Devices

J. S. Boyd
Member ASAE

W. H. Sheldon
Member ASAE

Concerned with the dangers of contaminated water supplies the authors report on a testing procedure for detecting back siphonage of livestock watering devices before installation

BACK siphonage refers to water flowing from a plumbing fixture back into the pipe which normally supplies water to the fixture. Back siphonage is most likely to occur through a submerged inlet if the pressure on the water supply is suddenly reduced to less than atmospheric pressure when the fixture is full of water and the inlet open. If back siphonage does occur, it may cause pollution of the water supply. The likelihood of disease transmission depends on the microorganisms present and the use which is made of the polluted water. In 1933 there occurred in Chicago an outbreak of amoebic dysentery which was attributed to back siphonage of water from a bathtub which was filled to the overflow thereby submerging the inlet. Bathtubs in hotels now have the inlets above the rim of the tub. In 1938 at Michigan State University an outbreak of goat-type undulant fever among students was traced to back siphonage of water from a laboratory sink through a hose attached to a faucet. Test tubes were being washed when the water supply to the building was suddenly shut off. More recently there appeared in the *Nebraska Alumnus* (2)* an article describing an outbreak of polio at Huskerville in which two died and eighteen were left paralyzed. The severity of this outbreak was attributed in part to back siphonage of water from several toilet bowls into the drinking water supply. From examples such as these and the fact that modern conditions on farms increase the hazards of back siphonage from livestock watering devices, a movement has been started by the USPHS (United States Public Health Service) to introduce preventive measures. The 1953 revision of the USPHS code, item 7-1113, reads as follows: "Submerged inlets in cattle drinking cups, wash vats, etc., should be avoided" (1). This revision of the code does not call for the replacement of any watering devices now in use. It does indicate to manufacturers that back siphonage is a recognized hazard and that, at some time in the future, farmers will be permitted to install only those watering devices which cannot backsiphon.

The purpose of the test described in this paper is to determine, before it is sold to the farmer, whether or not a watering device will back siphon. This eliminates the problems involved in having sanitarians measure each installation and possibly reject a unit once it is in place. This protects the farmer from buying units that can be declared unsafe by the local authorities and helps the public health people because each watering device will not have to be checked. Having passed this test the particular unit will meet the requirements of paragraph 15 of American Standards Associations designation ASA 40.4–1942 (3).

With the full cooperation of the USPHS and the Barn Equipment Association, a program has been established at Michigan State University for testing livestock watering devices under severe back-siphonage conditions. The objectives agreed upon in December, 1955, were: *(a)* The test should be positive. There should be visible evidence if any water is backsiphoned. *(b)* The test should be simple to perform with facilities that are easy to duplicate. *(c)* The testing conditions should be more severe than likely to be encountered in any farm installation. *(d)* The design of the watering device should be such that it has an air gap of sufficient size below the water inlet and above the rim so that back siphonage cannot occur. Check valves and other mechanical devices cannot be depended upon to prevent back siphonage because they may change with use or abuse. *(e)* The company would be permitted to use the letters

Paper presented at the Winter Meeting of ASAE in Chicago, Ill., December 1956, on a program arranged by the Electric Power and Processing Division, and approved as Journal Article No. 2217 of the Michigan Agricultural Experiment Station.

The authors—J. S. Boyd and W. H. Sheldon—are, respectively, associate professor and assistant professor of agricultural engineering, Michigan State University, East Lansing, Mich.

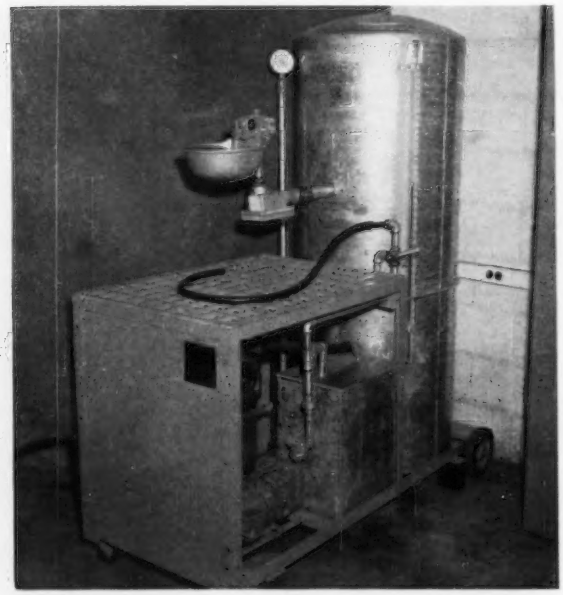

Fig. 1 Back siphonage tester for livestock watering devices

*Numbers in parentheses refer to the appended references.

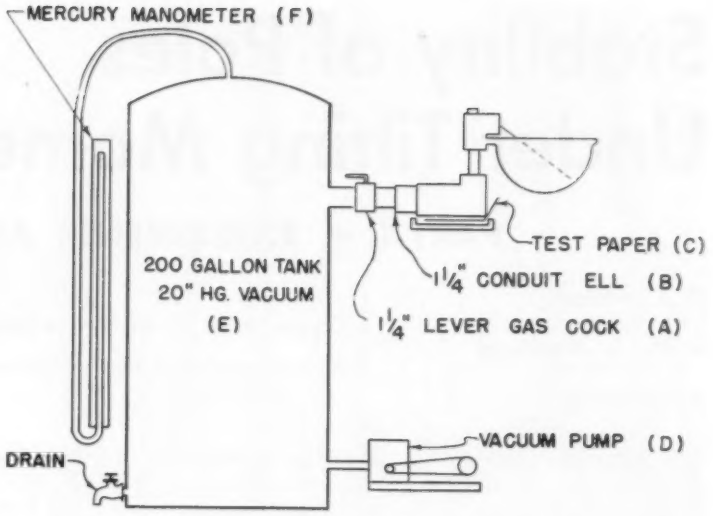

Fig. 2 Drawing of back siphonage tester shows manner in which test paper reveals contamination in water

"NS" as a prefix before the model number of a watering device that passed the test, as a means of identifying it as a non-siphoning watering device. *(f)* Based upon these tests, the USPHS would issue to all sanitarians a list of livestock watering devices which have satisfactorily passed this test.

Testing Procedure

A watering device to be tested is attached to a tank as shown in Fig. 2 and mounted in the same position as in a normal installation. It is then filled with tinted water. A test paper (C) is placed in the vacuum line, the tank is pumped to a 20-in. vacuum as measured by a mercury manometer (F), the nose paddle is depressed to hold the inlet valve fully open so that air may rush across the water and into the vacuum tank until the vacuum has been reduced to 10 in. of mercury. The main valve (A) is then closed and the test paper removed and inspected for dampness. The procedure is repeated twice. The device has passed the test if all three test papers remain dry. These test papers become part of the permanent record. The original report of the test is sent to the company requesting the test. One copy is sent to the Barn Equipment Association, one copy is sent to the USPHS and the other copy remains at the testing center. To date, 26 livestock watering devices have been tested. Of these, five failed the test and three of those which failed have been redesigned and subsequently passed the test.

The test is sensitive. In the development of the procedure, it was found that as little as four drops of tinted water passing through a water-bowl valve would make a visible stain on the test paper. When testing a watering device, the results are definite. If any water back siphons, a substantial quantity flows for some time giving both audible and visual evidence. Of those five devices that failed the test, back siphonage lowered the level of the water in one bowl by ⅜ in., in two others by approximately ¾ in., in another by 2 in., and completely emptied the fifth water bowl. The same results are obtained with repeated trials. The equipment illustrated in Fig. 1 uses a standard 120-gal pressure tank from which the air is exhausted with a milking machine pump. To the tank is attached a 1¼-in. gas cock and a 1¼-in. conduit ell. The test paper is clamped in the L.B. conduit ell fitting in a horizontal plane. The bowl to be tested is attached to a short riser pipe so that any back siphonage will be carried downward onto the test paper. For convenience in filling and emptying the watering device, there is a small shallow well jet pump connected to a reservoir with a positive head on the suction and a restriction in the discharge to the reservoir. A short length of ½-in. hose is attached to both the suction and the discharge of the pump through a 3-way valve. The watering device may be either filled or emptied through this one hose depending on the setting of the 3-way valve. The working surface of the equipment is a wooden grille lying in a sheet metal pan with a drain to the water reservoir.

Any company desiring that a test be made may secure application blanks and instructions from the Barn Equipment Association, 330 S. Wells St., Chicago, Ill., or from the Agricultural Engineering Department, Michigan State University, East Lansing, Mich.

References

1 USPHS Milk ordinance and code, U.S. Department of Health Education and Welfare, Public Health Service, U. S. Government Printing Office, Washington 25, D. C.

2 Polio epidemic factor found, *Nebraska Alumnus*, April, 1956.

3 Air gaps and backflow preventers in plumbing systems, ASA 40.4—1942, American Society of Mechanical Engineers, New York.

. . . Resistance to Air Flow

(Continued from page 163)

move the required amount of air against static pressures up to 20 in. of water. Overload protection should be provided for motors driving fans of the type used in this test, or suitable "load limit" fans should be selected to prevent motor failure when operating with the system partially filled with cotton.

The purpose of the test reported here was to obtain basic information on the resistance offered by seed cotton to air flow for possible use in the design of seed cotton storage structures. The optimum amount of air needed to properly condition and prevent heating of damp seed cotton has not as yet been determined and will be the subject of future testing by the laboratory.

Stability of Poles Under Tilting Moments

PART I — EXPERIMENTS AND RESULTS

G. L. Nelson
Member ASAE
G. W. A. Mahoney
Member ASAE
J. I. Fryrear

Careful study of anchorage behavior under simulated load conditions reveals important design information for pole-type farm construction

IN RECENT years, the use of pressure-preservative treated poles as main framing members for farm and utility buildings has become increasingly widespread. One requirement for a soundly-engineered pole frame is that the poles be adequately anchored in the ground to give the structure stability against wind or other loads with horizontal components which develop tilting moments. Therefore, it seems important to understand how the below-grade anchorage affects rigidity of a pole frame under horizontal loads.

Previous Work

Previous investigations on stability of poles and piling under horizontal loads have been conducted because of the need by utility companies, erectors of outdoor signs, and piling engineers for design data. Results have been reported by Anderson (1),* Browne and Fontaine (2), Chang (3), Cummings (4), Feagin (5), Seiler (7), Shilts (8), and Terzaghi (10).

The application of their results to anchorage of poles for farm buildings is limited by assumptions in some of the analyses that the embedments are deeper than is usual for farm building erection; that shear failure occurs in the soil around the anchorage; or that the soil profile is homogeneous with a known elastic constant. The relatively shallow settings for poles used in farm construction require that a portion of the overturning moment be resisted by somewhat loosely-consolidated material near the ground surface, and by a heterogeneous soil profile. Hence, an analysis which requires elastic constants and assumption of a homogeneous profile may be quantitatively unreliable when applied to the zone within a few feet of the ground surface.

The assumption of loading to shear failure in the soil and complete overturning of the pole does not seem applicable to poles used as framing members for farm building erection, because this would require movements of several feet at the top of poles of ordinary length. This amount of movement could, of course, not be applied to an ordinary building frame without serious structural damage to the building. Hence, consideration needs to be given to movement of poles under loads smaller than would cause overturning.

Preliminary report presented at the annual meeting of the American Society of Agricultural Engineers at the University of Illinois, Urbana, Ill., June, 1955, on a program arranged by the Farm Structures Division.

The authors — G. L. NELSON, G. W. MAHONEY, and J. I. FRYREAR — are, respectively, professor, assistant professor of agricultural engineering, and agricultural engineering draftsman, Oklahoma Agricultural Experiment Station, Oklahoma State University, Stillwater, Okla.

ACKNOWLEDGMENT: The authors wish to express their appreciation for the cooperation and assistance of the Farm Fencing Association, the Southwestern Creosoting Co. of Muskogee, Okla., and W. A. Stacey of the American Wood Preservers Institute.

*Numbers in parentheses refer to the appended references.

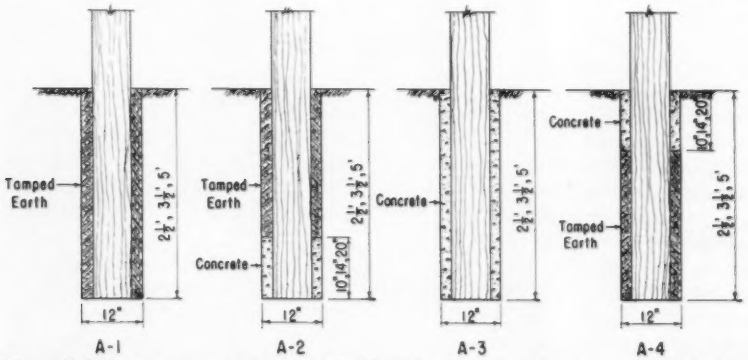

Fig. 1 Pole anchorages used in experimental testing program: A-1 is tamped earth, A-2 has concrete collar cast for lower one-third of below-grade portion with remainder tamped earth, A-3 is concrete, A-4 has concrete collar for upper one-third of below-grade portion with remainder tamped earth

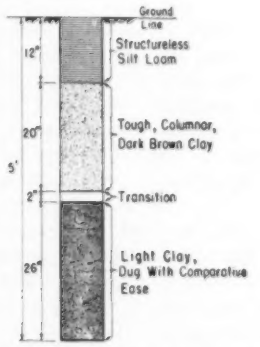

Fig. 2 Typical soil profile at site of pole anchorage tests

Fig. 3 Testing equipment, including weight basket suspended from a swinging bracket carrying a pulley block, and a cable to the top of the test pole

Experimental Testing

In order to investigate how depth and manner of anchorage of poles at shallow settings affect rotation and movement under moments due to horizontal loads an experimental testing program was set up at the Oklahoma Agricultural Experimental Station, Stillwater.

It was decided from consideration of current farm building practices and recommendations to test three depths of setting in the ground including 2½ ft, 3½ft, and 5 ft; and four kinds of end anchorage with the designations A-1, A-2, A-3, and A-4 as shown in Fig. 1.

Type A-1 consisted of tamped earth, and is representative of common practice for anchoring poles. Type A-2 included a concrete collar cast around the lower third of the below-grade portion of the pole, with earth backfill for the remainder of the anchorage. Type A-3 was completely encased in concrete below grade. Type A-4 included earth backfill for the lower two-thirds of the anchorage, with a concrete collar around the upper third.

A minimum of three replications of each depth and anchorage type appeared desirable to facilitate analysis of the data by statistical methods. The site selected for installation of the test poles was on a former barnyard overgrown with grass and weeds. The site was generally flat, but crossed by small dead furrows which acted as drainage channels. A typical soil profile for the site is shown in Fig. 2.

Soils in this general area are Bethany and Kirkland silt loams. These belong to the Reddish Prairie Great Soil Group which extends from South Central Kansas through Oklahoma into North Central Texas. A typical Kirkland series soil has approximately 40 to 50 percent clay in the "B" horizon and 35 to 40 percent clay in the "C" horizon. A consolidation test on a sample from the "B" horizon taken 2 ft below the ground surface at the test site indicated that this soil had been subjected to a preconsolidation load due to previous overburden of approximately 1 ton per sq ft. Void ratios were: approximately 0.56 for undisturbed soil; 0.38 at a consolidation pressure of 10 tons per sq ft; and 0.51 after unloading.

Test poles were placed in three 30-ft-diam rings with 12 poles uniformly spaced around each ring. The centers of the rings were at the corners of an equilateral triangle with 40-ft sides, which covered an area of uniform soil type, elevation, and drainage conditions. Each ring was divided into three sectors, in each of which four were set, with all four at one of the chosen depths but with one each of the four anchorages to be tested. Thus, one each of the anchorage types was randomly located in each depth sector, and the depth sectors were randomly located around each ring. Holes for the poles were dug with a 12-in.-diam auger. The earth backfill in all instances was tamped with a ⅞-in. round reinforcing bar 5 ft long with a bullet-shaped end and a weight of approximately 10 lb. The tamping procedure consisted in back-filling in 6-in. layers. Each layer was uniformily tamped with 30, 2-ft-high strokes of the tool. The loading experiments started on September 26 and were completed on November 5. A minimum time of approximately 29 weeks in the spring, summer, and early fall elapsed between completion of setting the poles and beginning of the test loading program. During this time, the earth around the poles had opportunity to attain a more uniform moisture content and condition of consolidation.

The poles were nominal 5-in.-top poles donated by the Farm Fencing Association through the Southwestern Creosoting Co., Muskogee, Oklahoma. All were treated with an 8-lb retention of No. 1 Creosote oil in accordance with ASA specifications. Twelve of the poles were nominally 18 ft long, and 24 were 20 ft long. The 18-ft poles were used

for the 2½-ft-deep anchorage installations while the 20-ft poles were employed for the 3½ and 5-ft installations. In addition, a 24-ft Class 4 pole was set in concrete in the center of each ring to serve as a support for the pulley block carrying the cable used to load the experimental poles.

Before the poles were placed, perimeters of each pole were measured at the butt and at 2-ft intervals to the tip. Analysis of linear regression of equivalent diameter versus distance from butt indicated that the 20-ft poles had a mean taper, or decrease in diameter of 0.0813 in. per ft of pole length; and the 18-ft poles had a corresponding taper of 0.0673 in. per ft. The regression expressions obtained were, for the 20-ft poles, $Y=6.881-0.0813X$; and for the 18-ft poles, $Y=6.595-0.0673X$, where Y is the estimated pole diameter in inches and X is the distance in feet from the butt of the pole.

Testing Methods

The general objective used as a guide in planning the loading method was simulation of horizontal components of wind forces on buildings. Maximum wind loads are due to gusts, which increase in intensity over a short period of time. Wind loads are generally assumed to have their maximum intensity over a 5-min period. Hence, it was decided to load the poles with a horizontal pull applied at 14 ft above the ground, and varied according to a predetermined time pattern from 0 to 800 lb maximum. Equipment to apply the loads consisted of a bracket carrying a pulley block and mounted on the center pole in each ring. A steel cable through the pulley block extended horizontally to a collar at the 14-ft elevation on the test pole. The other end of the cable hung downward to a weight basket. Concrete cylinders weighing 100 lbs were cast for weights. The loading procedure consisted of placing one 100-lb concrete cylinder in the weight basket each minute until the 800-lb maximum load was reached, then waiting 5 min, and finally removing one cylinder per minute. This cycle was applied three times to each pole. The general arrangement of the loading equipment is shown in Fig. 3. Measurements of horizontal movement of the pole were made at points 6 in. and 14 ft above the ground line, respectively. At the 6-in. level, a micrometer dial with a 4-in. range and reading to 1/1000 in. was clamped to a steel bar supported at each end by heavy steel tripods. Deflection measurements at the 14-ft level were made by means of a 3-ft horizontal scale reading to 0.2 in. mounted on a pendulum free to swing in two planes. This device was suspended on a bracket screwed to the pole. Readings on the scale were obtained by a transit telescope. By virtue of freedom of the device to swing in two planes, the horizontal movement of the pole was read even though the pole top rotated away from the vertical. Deflection readings at both levels were taken immediately before application of each load increment, and one-half min (30 sec) later.

Soil moisture samples to a depth of 5 ft were taken at three stations in each ring of test poles at intervals during the experiments.

Data and Results

A typical deflection-time plot of the observed data for anchorage A-1 depth 3½ ft, is shown in Fig. 4. The plotted data are those taken at ½-min intervals between application or removal of 100-lb load increments. It is apparent that the data provided a fairly well defined slope of the deflection-time curve. The movement during the five minute constant load period was always small compared to movement during loading or unloading.

Deflection-time diagrams for the 3½ and 5-ft depth and four types of anchorage are presented in Fig. 5. These were constructed by joining with a straight line the average deflections at the end of each phase of the loading schedule.

Several of the anchorages in the 2½-ft depth group allowed so much movement that the limits of the deflection measuring equipment were exceeded before a full 800-lb load could be applied. These included two poles in anchorage A-1; and, one each in anchorages A-2 and A-4. For this reason, deflection diagrams for the 2½-ft depth settings are not included, since they would not be comparable with those for the 3½ and 5-ft depths.

Average slopes of the deflection-time curves for all

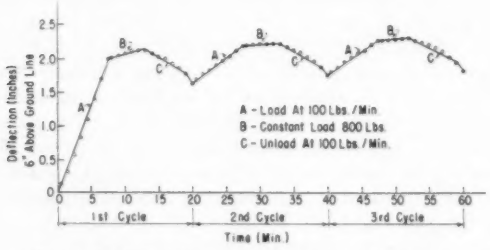
Deflection (inches) 6" Above Ground Line
A - Load At 100 Lbs./Min.
B - Constant Load 800 Lbs.
C - Unload At 100 Lbs./Min.
1st Cycle
2nd Cycle
3rd Cycle
Time (Min.)

Fig. 4 Deflection-time plot of deflection data for a single pole, anchorage A-1 depth 3½ ft

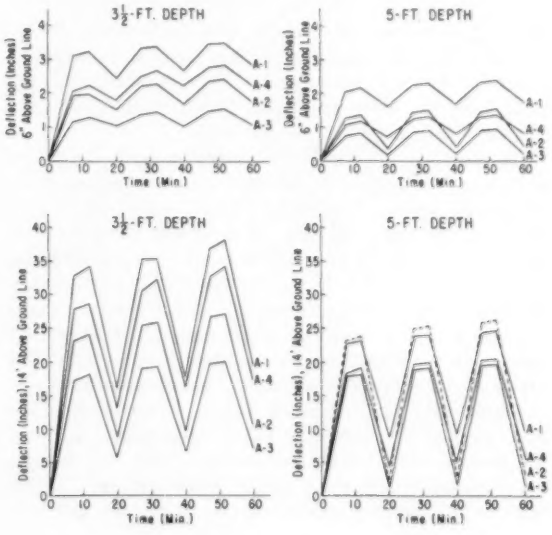

Fig. 5 Reconstructed deflection-time diagrams for averages of three poles

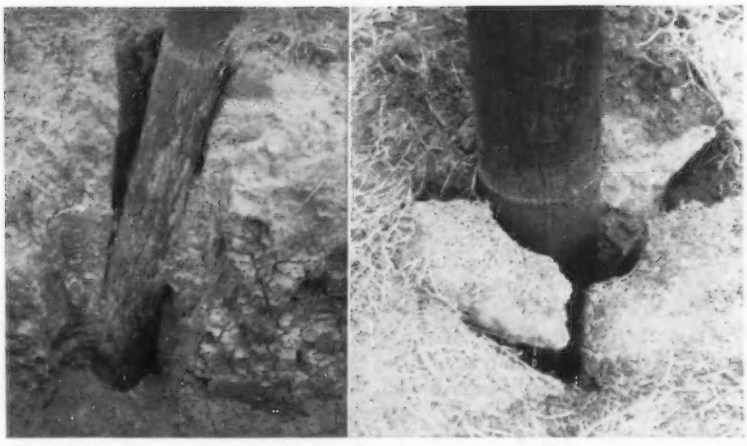

Fig. 6 Below-grade condition of pole anchorage A-1, 3½-ft depth after completion of loading tests. • Fig. 7 Appearance at grade after completion of test loading for anchorage A-4, 3½-ft depth

depths were computed from straight lines eyefitted to the deflection-time coordinates in the loading and unloading phases of each cycle. The rates as computed from fitted lines were subjected to statistical analysis of variance according to the method outlined by Snedecor (9) for three criteria of classification (anchorage type, depth, and cycle). Separate analyses were carried out for the deflection rates during application and removal of load, respectively. The results of these analyses are summarized in Table 1 for deflection and recovery rates at the 6-in. elevation and in Table 2 for rates at the 14-ft elevation. The mean squares for poles treated alike were used throughout the analyses for computing the f value for each source of variance.

Deflection rates have dimensions of inches of horizontal movement per minute. However, since load was applied or removed at a constant average rate of 1400 ft-lb per minute (100 lb per minute of horizontal load at 14 ft above ground line), the slopes might also be assigned the dimensions of inches per ft-lb of tilting moment provided the values in inches per minute are divided by 1400 ft-lb per min.

These deflection and recovery rates are an index of stability against tilting or rotation caused by the horizontal pull applied 14 ft above the ground. Higher rate during load application indicates less stability; while higher rate of recovery accompanying load removal indicates better recovery from tilt or rotation. The rates as measured by deflection data at 6 in. above the ground line give a better index of stability of the anchorage than the rates at 14 ft above the ground line, since the latter data will be affected by bending in the pole above the ground. However, a roof supported on a pole frame would respond primarily to horizontal movement at the pole top, regardless of whether it was caused by bending in the pole above the ground, or rotation of the pole in its anchorage.

The "Grouping" shown in Tables 1 and 2 indicates by a vertical bar the factors which are grouped together because of non-significant differences in mean deflection or recovery rates. For instance, in Table 1 the differences in mean deflection rates during loading of poles with 3½ and 5-ft deep anchorages were not significant; but the differences between deflection rates for the 2½-ft deep anchorages compared to the rates for the 3½ and 5-ft anchorages considered as a single group had an f value or variance ratio with a confidence level of 99.95 percent. The confidence levels shown in the tabulations were interpolated from tables by Hald (6).

It is evident that the important variation in loading deflection rate at both the 14-ft and 6-in. elevations was caused by the effect of concrete in the anchorage, insofar as anchorage type is concerned, and that variations among the deflection rates for anchorages with different amounts of concrete were not statistically significant.

First order interactions of anchorage type with depth during unloading exhibited an f value with a confidence level of 99.8 percent for recovery rates measured at 14-ft elevations and 99.95 percent for rates at 6-in. elevations. Examination of the recovery data indicated that the recovery

Factor	Effect During Loading				Effect During Unloading			
	Mean Deflection Rate		Analysis Of Variance		Mean Recovery Rate		Analysis Of Variance	
	In./Min.	Percent	Grouping	Confidence Level Percent	In./Min.	Percent	Grouping	Confidence Level Percent
Depth								
2½ Ft	0.3811	100.0			0.0788	100.0		
3½ Ft	0.1450	38.0	|	99.95	0.0692	95.8	|	99.70
5 Ft	0.1148	30.1			0.0917	125.8		
Anchorage Type								
A1	0.3345	100.0			0.0937	100.0	|	
A2	0.1715	48.3	|	99.10	0.0635	99.1		99.92
A3	0.1578	44.5			0.0703	75.1	|	
A4	0.1706	48.1			0.0642	68.6		
Loading Cycle								
1	0.4130	100.0			0.0777	100.0		
2	0.1240	30.0	|	99.95	0.0753	96.9	|	---
3	0.1038	25.1			0.0808	104.0		

Table 1 Effects of anchorage depth, type, and repeated loading cycles on movement of poles at 6 in. above ground line

Factor	Effect During Loading				Effect During Unloading			
	Mean Deflection Rate		Analysis Of Variance		Mean Recovery Rate		Analysis Of Variance	
	In./Min.	Percent	Grouping	Confidence Level Percent	In./Min.	Percent	Grouping	Confidence Level Percent
Depth								
2½ Ft	4.295	100.0			2.036	100.0	|	
3½ Ft	2.400	55.9	|	99.94	2.016	99.0		99.5
5 Ft	2.347	54.6			2.391	117.5		
Anchorage Type								
A1	4.222	100.0			2.300	100.0		
A2	2.785	66.0			2.228	96.8		
A3	2.401	56.9	|	99.3	2.078	90.4	|	99.92
A4	2.646	62.7			1.985	86.3		
Loading Cycle								
1	4.430	100.0			2.134	100.0		
2	2.318	52.3	|	99.95	2.144	100.9	|	---
3	2.293	51.8			2.175	102.4		

Table 2 Effects of anchorage depth, type, and repeated loading cycles on movement of poles at 14 ft above ground line

rates did not vary in a consistent manner with anchorage within a given depth. The minimum recovery rates were exhibited by anchorage A-2 in the 2½-ft depth, A-3 in the 3½-ft depth, and A-4 in the 5-ft depth. Maximum recovery rates were exhibited by anchorage A-1 in the 2½-ft depth and A-2 in the 3½ and 5-ft depths.

Examination of Anchorages

After completion of the testing program, examination pits were dug alongside one type A-1 anchorage in the 2½-ft depth group and alongside one of each anchorage type for the 3½-ft depth. After rough excavation was completed, the earth around one-half of the anchorage was carefully dug away with a spade and sharp knife. This permitted measurements to locate the point of rotation and amount of uplift. Fig. 6 illustrates typical voids developed by soil consolidation above and below the point of rotation. The estimated locations of the points of rotation, expressed as ratios of d/D, where d is depth to point of rotation and D is total anchorage depth were 0.637 for anchorage A-1; 0.595 for anchorage A-2; 0.548 for anchorage A-3; and 0.528 for anchorage A-4. In general, the point of rotation, or zero translation was quite well defined. No definite evidence of shear failure was noted in the zone of consolidated earth around the top and bottom of each anchorage respectively. The only discernible uplift was an upward movement of approximately ¾ in. by anchorage A-4 at the 3½-ft depth, and ¾ in. by anchorage A-1 at 2½-ft depth. It was noted that the concrete encasements in types A-2 and A-3 had ruptured along vertical lines. No circumferential cracking was noted. Many of the concrete collars for anchorages A-4 were cracked at the ground surface into several pie-shaped segments as indicated in Fig. 7. A few of the vertical cracks in the concrete encasements were creosote-stained. Apparently the concrete had cracked because of dimensional change in either the concrete or wood before the poles were load-tested. Other cracks appeared fresh and were without doubt caused by tangential tensile strain caused by bending of the pole under load. In either case, the cracks extended through the aggregate and hardened cement, and were not caused by weak or deteriorated concrete.

In the case of excavated anchorages A-1 and A-2, 3½-ft depth, the upper 12 to 15 in. zone of earth was not in contact with the pole in its tilted position. Examination at the ground line of other anchorages of Types A-1 and A-2 showed gaps of as much as ¾ in. from the pole to the inside of the hole in the direction of pull. This indicated that, because of inelastic behavior of this upper zone of soil, it was partially or completely ineffective in resisting overturning moment after the pole had been loaded once and then allowed to recover. In some cases, the earth at the ground surface on the loaded faces of anchorages A-1 and A-2 was slightly wrinkled. However, in no case was evidence noted of upheaval caused by shear failure.

Water Content of the Soil

Early in the analysis of the data, it was observed that considerable variation in deflection rate was occasioned by changes in soil water content. The loading experiments were started after prolonged dry weather, so that the water content of the soil averaged 13.3 percent, dry basis, during the loading tests in the first plot. Rains occurring subsequently increased the water content of the soil around the poles in the last plot tested to an average of 19.8 percent.

An analysis of variance was conducted on first cycle deflection rates as affected by soil water content in the first and last plots, respectively. The analysis yielded strong evidence that soil water contents above 17 percent caused radical increases in first cycle deflection rate as compared to water contents below 15 percent. The analysis further indicated that this effect was more severe in shallow as compared to deep anchorages. At soil water contents above 17 percent, first cycle mean deflection rate for 5-ft depths was 1.84 times as great as at water contents below 15 percent. This ratio had a value of 3.07 for the 3½-ft depth, and 7.55 for the 2½-ft depth. It should be noted that the water contents used in the analysis for the 2½ and 3½-ft anchorages were determinations for the upper 2-ft zone; and for the 5-ft anchorages were for the upper 3-ft zone.

Conclusions

Results from experiments involving only one type of soil profile should not be considered quantitatively valid for application to dissimilar soil profiles. However, it is believed that the results obtained from these experiments indicated the relative effects of anchorage type, depth, and repetitive loading in soil profiles which are predominately clay. Somewhat different behavior might be obtained for overturning moments of the same magnitude but produced by horizontal loads at heights other than 14 ft as was the case in these experiments.

Subject to these qualifications, the following conclusions are drawn with respect to the stability of anchorages in clayey soils for nominal 5-in.-top poles under overturning moments produced by loads increasing 100 lb per min up to 800 lb maximum applied 14 ft above the ground line:

- Shear failure and upheaval of clayey soils, even in relatively shallow anchorages for poles cannot be developed without movements much greater than a building frame could undergo without destruction or permanent damage. Hence, theories which are based on consideration of forces necessary to shear loose a wedge of earth are seldom applicable to evaluation of stability of anchorages for poles for farm or utility building frames.
- In order to improve the stability of pole anchorages in clayey soils, measures should be taken to *(a)* reduce consolidation pressures in the earth around the pole; *(b)* preconsolidate the soil and thereby increase its elastic modulus; and *(c)* eliminate loosely-consolidated backfill.
- Depth of setting of poles is one of the important factors which control the stability of pole anchorages. Increasing the depth of setting from 2½ to 3½ ft and 5 ft reduced movement to 38 percent and 30 percent, respectively, of the value at 2½ ft.
- The effect of depth was most pronounced on deflection rates during the first application of load. Subsequent applications of load tended to produce more uniform deflection rates for all the depths tested, although shallower anchorages had undergone greater permanent yielding.
- The effect of depth on deflection rates was less pronounced at the top of a long pole than at the ground line; since the top movement included bending of the pole above ground, which was independent of action below ground line, in addition to movement caused by rotation of anchorage and bending below grade.
- The ability to recover after removal of overturning moment is a most important factor in evaluating pole stability. The recovery rate accompanying removal of overturning moment

(Continued on page 172)

. . . Trends in Ball Bearings

(Continued from page 155)

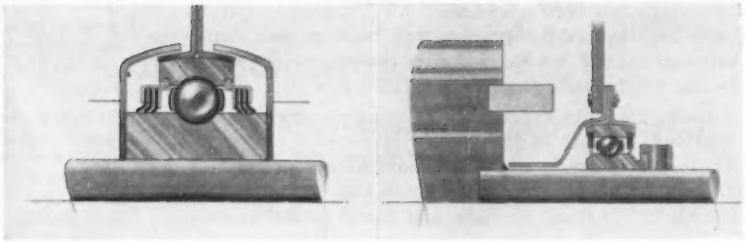

Fig. 12 *(Left)* A dirt shroud around a bearing which caused dirt packing. • Fig. 13 *(Right)* A close-clearance shroud and deflector pins mounted on the rotating part protect the bearing seal from grass wrappage

unit is preferred over the cast-iron type for reasons other than cost. These include applications where unbalanced loads, within the capacity of the stamping, tend to turn the outer ring in the housing or where the seal drag of a multi-sealed bearing tends to rotate the outer ring.

An important point to emphasize is that, in order to get satisfactory self-alignment, housings on both ends of the shaft must be self-aligning to avoid cramping the bearings. If one is not, then one bearing will be cramped even though the other bearing will allow angular shaft alignment around its own centerline.

The trend towards wide usage of different types of housed units in both pressed-metal and cast-iron constructions is becoming more pronounced due to economies of mass production at the bearing plants and the continuous search for newer and better units.

Important facts concerning lubricants, prelubrication, seals, and housed units have been presented in this paper. These facts when put together and applied to farm machinery are meaningless unless the result is a definite improvement in performance and life. Proof of improvement, unfortunately, has to come from the field – from the farm. Anyone who has ever made anything—from a birdhouse to a self-propelled combine—knows the alternate joys and sorrows that come from putting a product in this field.

In the following paragraphs are related a few recent field experiences in applying precision ball bearings to farm equipment.

Close clearance parts in an application, instead of effectively shrouding the bearing, may in some cases actually tend to pack dirt against the seal. This is especially apparent when the close-fitting part rotates with respect to the bearing seal, thus producing a grinding action which tends to wear away the seal.

One application involved an unsuccessful shroud (Fig. 12) which caused dirt packing. After the shrouds were removed, there was no further recurrence of the trouble. Unfortunately there is no hard and fast rule that tells whether a shroud should or should not be used. For instance, in applications where wrap is more of a problem than dirt, shrouding may be beneficial. In such cases the clearance between bearing seal and shroud should be relieved enough to prevent dirt from packing.

One of the most difficult application problems is keeping grass wrappage from ruining a bearing seal. The more successful designs which both farm machinery manufacturers and ball bearing engineers have developed utilizes a stationary shroud (Fig. 13) having close-fitting clearance with the shaft. Deflector pins mounted on the rotating part are also helpful. Close clearances may permit the entrance of moist dirt which in turn results in a serious corrosion condition.

A very difficult sealing problem exists when a bearing is subject to a dust-laden air stream. This is especially serious when there is a differential pressure between the outside and inside of the machine and the air has no escape except through the bearing. The most definite and best remedy is not to change the seals necessarily, although it may help, but to provide an easier escape path circumventing the bearing housing by means of openings on the machine frame. This can be accomplished by mounting the housing out from the side sheet thus allowing air to pass around the bearing, not through it.

In order to get performance results of prelubricated bearings in the field, we located a pull-type combine which was stored outside and had four years of service with about 2,000 hr estimated operation. The bearings were dismantled from all positions on the machine which included the cylinder shaft, cylinder beater, feeder beater, fan shaft and straw-walker shaft. Although some of the bearings showed slight penetration of dirt, the grease was smooth in consistency and plentiful in all bearings. This was severe service and illustrates the success of prelubricated ball bearings on farm machinery.

Another testimonial to the efficiency of prelubricated bearings has been found with triple-seal bearings on disk-harrow applications, such as one which harrowed 2200 acres of Arizona sand without failure.

One interesting field comparison of prelubrication versus relubrication (Figs. 14 and 15) involved relubricatable and non-relubricatable bearings incorporating contact seals which were run for 600 hr on the same bean harvester working in a cloud of dust. In each case, the grease in the bear-

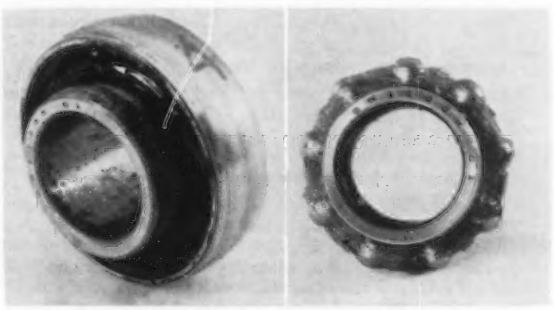

Fig. 14 *(Left)* Dirty grease and contaminants can be noted in this relubricated bearing after 600 hr of use in a bean harvester. • Fig. 15 *(Right)* This view shows clean grease in a prelubricated bearing after 600 hr use in a bean harvester. (Outer ring has been removed)

. . . Trends in Ball Bearings

ings, which had been relubricated in the field, was full of dirt while that in the prelubricated bearings was clean. Although the test was stopped after 600 hr, it seems quite obvious which bearing would have failed first.

Each new field experience or test application teaches something, and out of this practical experience new ideas in ball-bearing development for farm machinery are found. But have we learned enough to indicate that the trends will continue? We think we have, and based on that knowledge, we come up with this prognostication. The development revolution in the farm machinery and ball-bearing industries is accelerating the use of precision-type pre-lubricated ball bearings at most important turning points.

We predict that, with the advance of farm mechanization through the development of more automatic farm machinery, the grease gun will disappear from the modern farm as the oil can has vanished from the modern American home. In other words, all important turning points on farm machinery will be mounted on precision-type, prelubricated, efficiently sealed ball bearings.

New bearing materials and seal materials are being tested now and newer ones will be found. We will never wrap up in one package all the design features in a ball bearing required by all farm machinery manufacturers, but the ball bearing industry is dedicated to continue research which will promote development of new and better bearings mounted in new and better housings. These in turn will contribute greatly to the improvement of farm machinery for tomorrow, which will be obsolete the day after tomorrow.

. . . Stability of Poles

(Continued from page 170)

was about 25 percent greater for a 5-ft anchorage than for a 2½-ft anchorage, and almost ⅓ greater than for a 3½-ft anchorage.

- The use of concrete encasement instead of tamped earth for backfilling the space around a pole materially reduced the deflection rate of poles subjected to overturning moment. The use of concrete reduced deflection rate to ⅖ or less of values for anchorages backfilled with well-tamped earth. A concrete backfill not only reduces consolidation pressures, but also eliminates yielding due to consolidation or squeezing of inadequately consolidated backfill. Differences caused by partial as compared to complete filling with concrete were not statistically significant, although a complete filling produced the lowest deflection rate. Concrete encasements also helped to prevent loss in stability caused by increases in soil water content in the upper soil levels.
- Concrete encasements were fractured into pie-shaped fragments by vertical cracking either before or during loading of poles. A "barrel" or ring of welded wire mesh reinforcement in the encasement appears desirable to retain the effectiveness of the encasement during reapplications of load.
- Differences in deflection rate between the first and subsequent loading cycles were greater than those caused either by differences in anchorage or depth. Deflection rates during the second and third cycles of loading were less than one-third of the first cycle rate as measured near ground line, and about one-half as measured at the pole top. No significant differences existed among recovery rates for first and subsequent cycles.
- Because of the large reduction in deflection rate after the first loading cycle, preloading of pole anchorages to preconsolidate the soil around the pole anchorage should be tried in order to obtain maximum stability. Preloading could be accomplished by subjecting the poles to an overturning moment as great or somewhat greater than would be produced by service loads. After restoring the pole to a plumb position, the void developed could be grouted, or filled with other suitable material.
- Relatively small increases in water content of the soil around a pole anchorage can cause radical loss in stability in clayey soils. First cycle deflection rates were increased over seven times for 2½-ft deep anchorages when the soil water content of the upper 3-ft zone was 17 percent dry basis or higher as compared to deflection rates when the water content was below 15 percent. Therefore, precautions such as diversion of roof and surface drainage, and avoidance of poorly drained sites should be exercised when planning or building pole frame structures. The effect of moisture is more pronounced for shallower anchorages.
- Rotation of the anchorages occurred about a well-defined point which varied in depth but appeared to be below mid-depth and above ⅔ total depth.

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Special Short Courses Offered

TWO short courses on materials are being offered at Pennsylvania State University in June and July.

Closely allied with today's emphasis on research and development of rockets and guided missiles is the subject matter of the first course on Materials Engineering Design for High Temperatures which will be held June 29 to July 3. The second course is on Mechanical Properties of Materials and will be conducted from July 7 to 11.

The first course covers applications of materials used at high temperatures which include gas and steam turbines, aircraft engines, components of nuclear energy, and equipment used in the petroleum and chemical industries. The second course covers properties of metals, effects of radiation on metals, recent developments in testing machines and instrumentation, and metals under high speed loading.

Further information may be obtained by contacting Joseph Marin, Engineering Mechanics Dept., Pennsylvania State University, University Park, Pa.

Concepts, Terms, Definitions and Methods of Measurement for Soil Compaction

JOINT ASAE-SSSA SOIL COMPACTION COMMITTEE REPORT

THE increase in the importance of the soil compaction problem and the difficulty in solving its complexities give a need for new concepts, standardization of terms and definitions, and new methods of measurement.

I Soil Moisture

A. Soil Moisture Content

Introduction

The moisture content of soil is the principal factor determining its mechanical behavior and its measurement is indispensable in studies of soil compaction.

Definition

Moisture content of soil may be defined on an oven-dry weight basis or on a volume basis. The last method is preferable in all work dealing with agricultural soils, including soil compaction. The use of the oven-dry weight as a reference introduces the specific gravity of the solids. This property is irrelevant to soil-plant relations and also to soil compaction.

Moisture content by volume, M_v, is the volume of water per unit volume of soil, usually expressed as a percentage.

Moisture content by weight, M_w, is the weight of water per unit oven-dry weight of soil.

$$M_v = M_w \times (\text{bulk density})$$

Measurement

1 *Gravimetric*

A core of known volume is obtained (26, 32)* and its loss in weight upon drying at 105 C is determined. The loss in weight divided by the volume equals M_v.

If the bulk density of the soil is already known or if M_w only is required, samples may be taken with auger, tube, or shovel. The loss in weight upon drying divided by the dry weight of the sample equals M_w.

The gravimetric method is often the most practical, but sampling error may be high, requiring many samples (35).

2 *Neutron Moderation*

A source of fast neutrons affixed to a slow neutron counting device is placed in the soil by means of an access tube. The energy reduction of the fast neutrons to thermal (slow) neutrons is almost wholly accomplished through the presence of hydrogen in soil moisture. The density of the thermal neutron cloud surrounding the source is measured with the counter and is almost a linear function of the concentration of water—that is, M_v.

The method is fast, reliable, and universal. Its resolution is about 6 in. at present stage of development. Portable equipment has been devised (4, 21, 58, 66) and continues to be improved. Although some theoretical aspects of the method are not entirely understood, it appears to be the most promising non-destructive method.

3 *Thermal Conductivity*

The thermal conductivity of soil is dependent upon the moisture content by volume for a given soil. This principle was embodied in a device cited in reference 49. Recently the method has been much improved (16). Though the method has not been widely used and is not simple to use in field work, it is mentioned because it offers possibilities for studies on a small scale such as might occur in soil compaction work.

4 *Indirect Methods*

A number of methods consist of measuring physical properties of porous bodies in equilibrium with the soil. These should be more properly regarded as measurements of soil moisture pressure and will be discussed in the next section. However, they may serve as indirect means of determining soil moisture content.

B. Soil Water Pressure

Introduction

In unsaturated soils the pressure in the liquid phase is irrelevant to the mechanical properties of the material. In such cases the pressure is of interest only as an indication of the moisture content.

In saturated soils, soil water pressure is important to the mechanical behavior and the occurrence of failure depends not only upon load but upon the pressure in the soil (or pore) water (8a).

Soil compaction studies in agriculture will not often include saturated soils except in areas with high water tables or in certain drainage problems.

Definition

The pressure is the force per unit area on a plane of any direction at the point in question. Pressure of soil water may be negative or positive with reference to atmospheric pressure, which is the common reference. Pressure is measured in millibars (1 mb = 10^3 dyne cm^{-2}). Often, one uses a cm of water as a unit (1 cm hydraulic head = approximately 980 dyne cm^{-2}).

When pressure is positive soil is saturated, except for entrapped air. In unsaturated soils pressure is always negative. In saturated soils pressure may be negative or positive.

Measurement

1 *Positive Pressures*

These are measured with piezometers, i.e., tubes open at both ends and inserted to the point in question. The height of the water standing in the tube equals the pressure measured in units of length of a water column. To obtain the pressure in mb, multiply with the specific weight of water and the gravitational constant $\times$ 10^{-3}.

2 *Negative Pressures, less than 1000 mb*

Tensiometers measure negative pressure up to 1000 mb, depending upon equipment and precautions taken. A tensiometer is a special case of a piezometer. They are commercially available for several depths. Multiple tensiometers for profile studies have been developed (41, 43).

3 *Negative Pressures, more than 1000 mb*

Direct measurements of moisture tension (negative pressure) are not feasible when tension exceeds approximately 1000 mb. But it is possible to study the properties of a porous body that is in moisture equilibrium with the soil. The moisture content in such a body is determined by the moisture tension in the surrounding soil.

There is a question whether fluid pressures less than -1000 mb can exist in soil at all. At the low moisture contents associated with such low pressures the proximity of the solid-liquid boundary and the associated electrolytes determine the force field to which the water is subjected rather than gravity and surface tension which predominate at high moisture contents. However, we may still use the concept of tension, provided it is understood as an equivalent tension.

(a) Electrical Conductivity of Moisture Blocks

Gypsum, woven fiberglass, and nylon have been used separately and in combinations (5, 11) to obtain porous media, which would lose water throughout the tension range from 0 to 20 bars.

The resistance between two electrodes in the blocks is indicative of the moisture content of the blocks as well as of the electrolyte concentration. In practice, this means that use of conductivity blocks in saline soils is inadvisable.

In non-saline soils blocks still offer many problems such as individual calibration, change with time of the response curve, lag of response. However, the approximate value of the soil water tension can be measured with these devices.

(b) Electrical Capacitance of Moisture Blocks

Measurement of electrical capacitance in an equilibrium body would be less sensitive to electrolyte concentration than would a measurement of conductivity. Although several workers have occupied themselves with this method (2), no widely accepted solution has been presented. A recent development may be of practical interest (15).

*Numbers in parentheses refer to the appended references.

EDITOR'S NOTE: The purpose of the joint Soil Compaction Committee of American Society of Agricultural Engineers and the Soil Science Society of America was to assemble important physical concepts for future soil compaction research and to report definitions, methodology and instrumentation.

Methods of measurement and instrumentation are cited by principle but not in detail. For such the reader is referred to the references that are supplied. The Committee has not attempted to be complete in its compilation but rather has selected the information that appeared most promising.

Committee members are: (SSSA)—C. H. M. van Bavel, chairman, W. R. Gill, D. W. Henderson, W. D. Kemper, D. Swartzendruber, and J. R. Runkles. (ASAE — Subcommittee on Instrumentation of the Soil Compaction Committee)—A. W. Cooper, chairman, E. R. Allred, W. F. Buchele, J. K. Jensen, R. J. Sullivan, and Coby Lorenzen.

. . . Soil Compaction

All measurements of soil moisture tension, direct or indirect, can also serve as measurements of soil moisture content. This can be done with aid of a soil moisture characteristic obtained in the laboratory or by direct calibration of the measuring device in terms of moisture content. The latter method is actually most common where blocks are employed. It is important to realize that the measurement is subject to error due to the hysteresis of the moisture-tension relationship.

II Soil Internal Geometry

A. Total Porosity and Bulk Density

Introduction

Total porosity or bulk density supplies the most elementary information concerning the relative proportion of solids, water, and air. Its determination appears indispensable to all studies of compaction and of soil-plant relationships.

Definition

The total porosity of soil is the fraction of the volume not occupied by the oven-dry solids. In soil mechanics it is customary to speak of the porosity *(n)*.

Bulk density is the mass of the oven-dry solids per unit volume. It is more widely used than total porosity but the latter seems preferable because it implies nothing as to the nature of the solids.

Measurement

Measurement of total porosity or bulk density must be made on undisturbed samples. Four methods merit consideration in soil compaction research.

1 *Use of Core Samplers*

Cylindrical cores are obtained with hand tools (26, 32) or with power driven samplers. The oven-dry mass in a known volume is determined. This supplies the value of the bulk density *(D)*. A separate measurement of the density of the solids *(G)* or the assumption of a certain value for G is required to obtain the total porosity from:

$$n=1-D/G$$

The core method is by far the most widely used one although it presents difficulties in stony soils. Also, the possibility of compaction in the sampler is always present.

2 *Paraffin Method*

In this method a soil clod is covered with paraffin and subsequently weighed in air and in water. The difference in weight minus the volume of the paraffin supplies the volume of the clod. The oven-dry weight is also determined and one may proceed as under 1. This method is laborious but should be free of bias. It has been discussed recently in reference 48.

3 *Volumeter Method*

A volumetric method to determine bulk density changes in soil during compaction has been devised (59). The method employs a small balloon filled with the soil being studied. It is placed in the soil to be compacted. The balloon is connected in a closed system with a horizontal glass tube containing a drop of mercury. This volumeter indicates volume changes resulting from stresses in the soil. The final bulk density of the soil-filled balloon may be determined by the water displacement method and bulk density can be calculated for any state of stress. The change in bulk density in a tri-axial shear machine may be determined by the volumeter method.

4 *Gamma Transmission Method*

Although still under development, this method is mentioned since it is the only one capable of making a non-destructive measurement and, as such, it is especially suitable in soil compaction studies.

In essence, a gamma source, preferably Cs 137, is placed in soil and the radiation intensity is measured at a known distance. It appears essential that the measurement be made with a proportional device, excluding scattered radiation. The resolution of the method is about ½ in. and the precision about 0.01 g cm^{-3}. Measurements can be made in any soil at any moisture content and any depth. The radiation intensity is a measure of the wet bulk density. A separate measurement of moisture content is required to obtain total porosity or bulk density (57, 60).

In compaction studies of brief duration, however, it is not necessary to measure the moisture content more than once, for example, at the conclusion of the experiment. Also, in saturated soils the measurement of gamma transmission suffices to calculate total porosity, if a value for specific gravity of the solids may be assumed.

It may be pointed out here that when bulk density or total porosity are known, the gamma transmission method can also serve as a means of ascertaining the moisture content of soil.

B. Pore Size Distribution

Introduction

Next to total porosity, pore size distribution is the fundamental physical characteristic of soil. Pore size distribution determines the permeability for water and the manner in which water is held, although type of clay and adsorbed cations also play a role.

Definition

The pore size distribution is the fraction of the total soil volume occupied by pores of a diameter between d and $d+\Delta d$, as determined by the pore diameter d.

In actuality, soil pores are not at all cylindrical and the assignment of a certain pore diameter is based upon the tension required to drain certain pores assuming that the following relation holds:

$$d=4\,T/t$$

in which T is the surface tension and t the tension, both in c.g.s. units. In essence, therefore, there is no difference between the moisture characteristic and the pore size distribution (8).

For tensions not exceeding 100 mb the relation between pores drained and tension is most accurately found with a so-called tension table, of which numerous versions and descriptions have been given (29). Core samples are brought to equilibrium at certain tension values by means of a porous supporting platform.

For higher tensions, up to 1000 mb, it is better to raise the pressure in the gas phase rather than decrease the pressure in the liquid phase. This is the principle of the porous plate cell, of which the pressure cooker version is now most widely used (40, 42, 44, 46). Samples should preferably be core samples but not thicker than one inch, otherwise the time to reach equilibrium becomes quite long.

For the highest tensions, up to 20 b, the pressure membrane apparatus is used. Samples can be disturbed and should be spread in a thin layer of about ½ in. to obtain equilibrium in a short time (39).

C. Air Permeability

Introduction

Air permeability is not a physical property of soil influencing its mechanical behavior or its suitability for plant growth. However, it is a sensitive indication of soil internal geometry for comparative studies. Furthermore, some promising methods for its measurement under field conditions have been established.

Definition

The air permeability of soil is the quotient of the flow velocity of the air times its viscosity divided by the pressure gradient.

In formula: $v=k/\eta\ (dp/dx)$

in which k is the permeability and η the viscosity. In c.g.s. units k is measured in cm^2, but square microns (10^{-8}cm^2) are more practical for common use.

Measurement

Air permeability can be measured on core samples in a rather straight-forward manner. See, for example, reference 36.

Relatively simple and reliable field techniques have been developed, particularly to measure the air permeability of surface layers (17, 23). In all methods the pressure gradient, or the rate of pressure decrease or volume decrease, is observed as air is permitted to flow through a body of soil.

It should be emphasized that the values obtained are an expression of both moisture content and pore size distribution at the point of measurement.

D. Hydraulic Conductivity

Introduction

The hydraulic conductivity of soil, in saturated or unsaturated condition, refers to the readiness with which it transmits water. This factor is of the greatest significance to plant growth, trafficability, drainage, and infiltration. Often it is adversely affected by compaction of the soil.

Definition

The hydraulic conductivity of soil is the flow velocity of the water divided by the hydraulic gradient, or

$K=v/(dp/dx)$ for one dimension.

If p is expressed in cm water, K is in cm sec^{-1} in the c.g.s. system. Centimeters or inches per hour are more useful units.

If K is multiplied by the viscosity of water and divided by the product of water density and gravity, k is called the intrinsic permeability, with c.g.s. units of cm^2. In soils not altered by contact with water, k for air and for water are the same in the cases of air-dry soil and saturated soil, respectively.

Ordinarily it is sufficient to study values of K, the hydraulic conductivity. It is important to bear in mind that the value of K depends upon the moisture content. The maximum value occurs at saturation. As soil becomes less saturated the value of K decreases, usually quite sharply.

Measurement

Determination of the saturated conductivity has been a much studied problem and several methods are available. Unsaturated conductivity has been given less attention until recently.

1 *Soil cores.* This is the oldest method, in which cylindrical cores are taken and examined in a permeameter. Many versions are known, see, for example, references 36 and 55.

The core method has many drawbacks, for example, bacterial activity and disturbance due to sampling. But the principal

objections are the large sampling error and the difficulty experienced in taking core samples below the water table.

2 *Auger hole method.* This, as well as the following are field methods suitable only for the soil below the water table. They all consist of digging a cavity below the water table and observing the rate of entry in the cavity under prescribed conditions. In such methods the soil is studied in its natural state and the sampling error is reduced materially since the flow takes place in a large body of soil.

In the auger hole method the hole is made with an auger and remains uncased. The water is pumped out and the rate of rise is measured. Details are given in references 27 and 56.

3 *Piezometer method.* Here the hole is cased with a metal pipe. A cavity of known depth extends the hole beyond the pipe. The rate of rise after pumping out is determined. Details are given in references 27 and 31.

The piezometer method supplies a more localized value for permeability in contrast with the auger hole method.

4 *Two-well method.* In the auger hole method and the piezometer method no distinction is possible between horizontal and vertical components of saturated conductivity. Theoretically, the piezometer method can be adapted for such a purpose but the accuracy is poor. The two-well method (9, 10) was designed to measure horizontal permeability by observing the rate of flow from one well to another, when a hydraulic head difference between the two wells is maintained.

5 *Unsaturated conductivity.* Although values for unsaturated conductivity may be inferred from observed changes in moisture content of field soils, no field method for its direct measurement has been proposed.

Laboratory methods applying to disturbed samples have been suggested (45). The method suggested by Gardner (20) is particularly attractive since it may be carried out by observing the drainage rate of samples on conventional porous plate or pressure membrane apparatus. Presumably the method would be adaptable for use with core samples.

E. Infiltration Rate

Introduction

The ability of soil to absorb water from rain or flooding is a factor which is of the greatest significance in soil management and it may be drastically affected by compaction of the soil.

Definition

The infiltration rate is the volume of ponded water in an infinitely thin layer which passes into the soil per unit area and unit of time. It is measured usually in centimeters or inches per hour.

The infiltration rate is determined by the surface conditions and the internal geometry of the soil, but also by the moisture conditions in it, that is, the distribution of hydraulic head and the value of the hydraulic conductivity. As infiltration proceeds, its rate usually decreases until a minimum, steady value prevails.

Measurement

1. *Hydrograph analysis of watersheds or smaller controlled plots.* This method gives gross values that are of significance in hydrology and for designing moisture conserving practices.

It is extremely laborious and time-taking but undoubtedly the most reliable one (12, 64). The method would seem of little application in soil compaction research.

2 *Rainfall Simulator.* By sprinkling a small area at a known rate, reliable data on infiltration rate may be obtained (64, 65). Although the procedure is not simple, it is more feasible than the previous one.

3 *Basin Flooding.* Where flooding is an accepted and practical method of irrigation, the impoundment of water in basins of sizes up to 900 square feet can be used as a method to measure infiltration rate. The effect of lateral movement should be quite small in this procedure.

4 *Cylinder Infiltrometer.* The two previous methods require large quantities of water and are, therefore, not always practical. The cylinder infiltrometer is a small flooding device, which is convenient in operation. Its principal drawback is the unknown extent of lateral flow in many cases. This may be offset by the use of buffer ponds or buffer cylinders. A recent summary report is given in reference 24, other information is available in reference 6.

Cylinder infiltrometers are useful primarily for comparative studies. The absolute values are open to doubt, particularly when applied to infiltration of natural rainfall.

III Mechanical Strength of Soils

The resistance of a soil to deformation, i.e. compression and/or shear is determined by its mechanical strength. The strength of soil consists of two components: a cohesive strength and a frictional strength. The values vary considerably depending upon moisture content, particle size, aggregate size, and consolidation. These factors, among others, exist in so many different combinations that only direct measurements of cohesive and frictional components can determine the actual strength of a given soil in a given condition.

All materials of finite size have properties which lie between the extremes of the rigid, elastic solid, and viscous fluid. Soils with various physical properties and moisture contents can range from rigid, elastic solids through the plastic range to very viscous fluids. When the soil is elastic and is subjected to a load it deforms rapidly in an amount that is linearly proportional to the magnitude of the load and returns rapidly to its original shape when the load is removed. A plastic soil mass deforms indefinitely under a constant finite load with a non-isotropic state of stress. The deformation is maintained when the load is removed. The amount of deformation is proportional to the time the load was applied as well as the magnitude of the load. The cohesive value of the soil is important in plastic flow. Soils which are saturated and exhibit viscous fluid properties can have only an isotropic state of stress. The resistance to deformation is proportional to the rate of deformation.

In studying the compactibility of soil there are two phases to be considered. First, to determine the distribution of the stresses in the soil mass caused by the externally applied loads and, second, to predict the effect that these stresses will have on the soil mass. Since one of the effects of the stresses is to force a modification or redistribution of the stress pattern in the mass, the problems must be considered simultaneously.

A. Measurement of Stress Distribution in Soil

A number of pressure cells have been developed in an attempt to measure pressures in soil (61) employing various physical principles. Recently, relatively flat rigid cells utilizing electrical resistance strain gages have been developed (61, 13). These cells give reasonably close uniaxial stress measurements in uncemented soils and can be oriented in definite directions under symmetrical loads to measure stress components necessary to describe the stress state. By a series of measurements the stress distribution in the soil under a load can be determined for a given soil at a given moisture content.

Terzaghi (54) gives a discussion of the stress conditions for failure in soils. He uses an empirical equation known as Coulomb's equation:

$$S = C + P \tan \phi$$

where S = shearing resistance, psi

P = normal stress, psi

ϕ = angle of internal friction

C = apparent cohesion, psi

The values C and ϕ can be determined by means of laboratory tests by measuring the shearing resistance on plane sections through a soil at different values of the normal stress. Several types of devices have been used to measure shear, the direct shear devices (34, 47, 25), the triaxial shear machine (51), ring shear apparatus (63), circular shear device (19), and vane shear (18).

Terzaghi (54) discusses the use of Mohr's circle to analyze shear data. It furnishes a convenient graphical representation of the relation between principal stresses and the shearing and normal stresses. The apparent C value in Coulomb's equation can be determined by using Mohr's envelope by making two or more measurements of the shearing stress at different normal stresses, plotting the Mohr's circles drawing the tangent line to the circles and determining the height of the Y intercept at $X=0$.

Another direct method of measuring cohesion can be accomplished by a simple tensile strength apparatus (34). Results are reported in pounds per square inch or in bars. A core sampler apparatus has been devised (52) to measure soil cohesion. A cylinder made up of two sections bolted together was driven into the soil. The sections were then unbolted and the force required to pull the top section up when the soil between the sections failed was measured. Knowing the weight of the upper cylinder section and soil and the area fractured, the cohesion may be calculated. The modulus of rupture is another soil strength measurement that has been investigated by several workers (53, 1, 7, 38). This measurement determines the force required to break a known cross section block of soil as a beam.

B. Measurement of Soil Reaction to Stress

Changes in bulk density and particle displacement have been the most widely used methods of measuring the reaction of soil to stress. These are discussed in sections II and IV of this report.

Several laboratory methods have been used to determine the reactions of soil to stress: static confined compression test (37), vibrating load confined compression test (37), impact loading test (28), and unconfined compression (3).

Other methods for determining reaction of soils to stress are the effect of the stress on change in water infiltration and permeability and change in air permeability.

IV Particle Displacement

The displacement of particles within a soil mass may change the pore size distribution or the continuity of the pores so that

. . . Soil Compaction

the infiltration rate of water, the permeability to air and water, and the moisture retention curve may be affected. Generally, the over-all effect of particle displacement is indicated in the measurement of bulk density. However, in order to understand what takes place on occasion, it is desirable to measure individual particle displacement. Both relative and absolute displacements are significant.

Definitions:

1 *Displacement* — the difference between the initial position of a body and any later position.

2 *Absolute displacement* — displacement with respect to a datum, which is commonly the initial position of the particle.

3 *Relative displacement* — displacement (including rotation) relative to the position of other particles.

Measurement of displacement: A tracer may be placed at predetermined positions within soil samples, especially if artificially packed, and absolute or relative displacement of the tracer measured. Tracers may take a variety of forms, including rigid plates, beads, membranes, or powdered materials. Plates may be metallic and thus their positions detected by electric or magnetic properties. Their presence may alter the stress distribution within the soil. Membranes usually must be capable of visual detection and must have negligible tensile strength, and for this reason cohesionless white powders are preferred. Lime and gypsum have been used successfully (30, 50). Proper placement of bands or layers allows measurement of both vertical and horizontal displacements which may be recorded photographically. McKibben and Green (33) used small colored beads to follow soil displacement. Gliemeroth (22) photographed on high speed movie film the path of particle movement under tires and tracks. Reaves and Nichols (37) traced movements of soil particles along a powdered aluminum covered glass sided box.

Day and Holmgren (14) used photomicrographs to characterize structural arrangements or aggregates of different soils after compression at different moisture contents. This and other photographic techniques indicate the general pattern of displacements occurring if photographs are taken before and after compaction. The Waterways Experiment Station (62) used a differential transformer type device to measure displacement of soil. This device, which is a strain gage, is capable of measuring displacement of 1/10,000 in.

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Fifth Agricultural Engineering International Congress

The Fifth International Congress of Agricultural Engineering, sponsored by the Commission Internationale de Genie Rural, will meet September 29 to October 4 during the World Fair in Brussels, Belgium. The aim of the congress is to stimulate the science and the techniques of agricultural engineering, as well as the use of these techniques; and to co-ordinate scientific research and techniques in the fields related to agricultural engineering.

The program will be divided into four sections and discussions will cover topics concerning soil science with application in the field of agricultural engineering (techniques of soil conservation, drainage, irrigation and land improvement); farm buildings and connected equipment; agricultural machinery and rural electrification; and farm work and processing program. Visits and excursions to places of interest will be scheduled.

National delegates will attend from 16 different participating countries. By this congress the C.I.G.R. hopes to ensure continuity in the purpose to serve agriculture by developing engineering science, and by placing it at the disposal of the great world organizations.

Registration information may be obtained by writing to M. Nestor Laret, Avenue des Combattants, 69, Gembloux, Belgium. Specialists interested in presenting a paper should write to the Secretary of the Congress, Vth International Congress of Agricultural Engineering, Commission Internationale de Genie Rural, Gembloux, Belgium.

International Agricultural Machinery Show

The International Agricultural Machinery Show will be held at Strasburg, France, March 29 to April 3. The show and the general agricultural contest will be held in the same building and will constitute the 1958 Agricultural Week.

The aim is to present to French and foreign professionals and farmers, not only an insight into the mechanical means actually available for the equipping and modernization of agriculture, but above all, a synthesis of what could best be done in this field.

The European Economic Community Treaty goes into effect this year and it is hoped by cooperating countries that these developments will form the first stage of an irreversible evolution towards the economic unity of Europe and the creation of a market on the scale of today's vast International currents (volume) of exchange, of the putting into action of better methods of production and of a constantly increasing consumption due to the rise in the standard of living of the western peoples. The International Agricultural Machinery Show is one of the first large international shows placed under the sign of the European Common Market.

EJC Regional Meeting

A one-day regional meeting of Engineers Joint Council, sponsored locally by the Western Society of Engineers, an EJC member, will be held at the Sherman Hotel, Chicago, May 19.

The theme "The Next Decade in Engineering" will be considered in a series of meetings which will include topics on survey of the profession, education and manpower, basic and applied research, and government in science and engineering. These subjects will be presented by prominent speakers and will be of interest to all engineers.

Local sections of the EJC societies are cooperating in the meeting.

Irrigation Clinic

The second annual Irrigation Clinic will be held at the University of Illinois, Urbana, on Thursday, March 20, 1958. The course is planned for designers, distributors, dealers, users and others interested in irrigation in Illinois.

Subjects dealing with water rights, plant-soil-water relationships, pumps, equipment standards, labor saving and Illinois farm irrigation experiences will be included on the program. ASAE members participating in the Clinic include Ralph C. Hay, Frank B. Lanham, Guy O. Woodward, and Keith H. Beauchamp.

Those interested in attending the course should register in advance with the Division of University Extension, University of Illinois, Urbana, Ill.

T. W. Edminster, assistant to the section head in program coordination and administration, (SWCRB, ARS) USDA, Plant Industry Station, Beltsville, Md., is visiting professor in the Irrigation Science Dept. at the University of California, Davis. He will be there until June.

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Paul R. Hoff, while on sabbatical leave from Cornell University, will serve as agricultural engineer, International Cooperation Administration in Mexico.

•

Nolan Mitchell has been promoted to vice-president and director of the sales program at Aerovent Fan & Equipment, Inc., Lansing, Mich. Formerly he was sales manager for the company. In addition to his new duties as vice-president he will be responsible for expansion of the export division.

•

Boy Bainer, past-president of ASAE, and chairman of the agricultural engineering dept., University of California, Davis, will be in Chile until March 22 as associate director of a school for agricultural officials of ten South American countries. Mr. Bainer will lecture on problems relating to selection, operation, and maintenance of agricultural and land development machinery.

•

John M. Johnson has been appointed agricultural extension engineer with the University of Tennessee Agricultural Extension Service. A native of Florida, Mr. Johnson received B.S. and M.S. degrees in agricultural engineering from the University of Florida. Formerly he was manager of the agricultural engineering division for the Moore Dry Kiln Co. in Jacksonville, Fla.

He has served as chairman of the Florida State Section of ASAE and president of the Florida Irrigation Association.

EVENTS CALENDAR

March 17-21 — *1958 Nuclear Congress* will be held at the Chicago Amphitheatre, Chicago, Ill. It is managed by the American Institute of Chemical Engineers and coordinated by the Engineers Joint Council and will include the 4th Nuclear Engineering and Science Conference, 4th International Atomic Exposition, 6th Atomic Energy in Industry Conference, 6th Hot Laboratories and Equipment Conference, and the American Power Conference. For further information write to Engineers Joint Council, 29 West 39th St., New York 18, N. Y.

March 16-22 — *National Wildlife Week* will stress the need for conserving public lands—parks and forests, wildlife, wilderness areas, grazing and mineral lands.

March 20 — *Irrigation Clinic* will be held at the University of Illinois, Urbana. Those interested in attending the course should register in advance with the Division of University Extension, University of Illinois, Urbana, Ill.

March 20-21 — *Textile Engineering Conference* of The American Society of Mechanical Engineers, North Carolina State College, Raleigh, N. C. The theme will be on cost control through engineering. For further information contact Professor A. W. Futrell, Mechanical Engineering Dept., No. Carolina State College, Raleigh, N.C.

March 23-29 — *American Congress on Surveying and Mapping and the American Society of Photogrammetry Consecutive Meetings and Co-Exhibit,* Shoreham Hotel, Washington, D.C. For further information write ACSM-ASP, 1515 Massachusetts Ave., N.W., Washington 5, D.C.

March 29 to April 3 — *International Agricultural Machinery Show* to be held at Strasburg, France. For further information write to Salon International de la Machine Agricole, 95 Rue Saint-Lazare, Paris, France.

April 11-18 — *Fifteenth International Horticultural Congress,* Nice, France, on the Cote d'Azur. The theme will be on science in the service of horticultural techniques.

May 5-7 — Thirteenth *Purdue Industrial Waste Conference,* Purdue Memorial Union Building, Purdue University, Lafayette, Ind. Registration blanks will be mailed upon request to D. E. Bloodgood, School of Civil Engineering, Purdue University, Lafayette, Ind.

May 12-15 — *Crop Protection and Pest Control Exhibition,* Royal Horticultural Society's New Hall, London, England. The exhibition will be concerned largely with weed and pest control in agriculture and horticulture, but will also deal with domestic and industrial pests. It is organized by "World Crops," the international journal of agriculture.

(Continued on page 195)

Pacific Coast Section

The Pacific Coast Section held a meeting January 30, 1958, at the University of California, Los Angeles. Officers for the coming year are Lloyd H. Lamouria, chairman; Samuel V. Gunnison, vice-chairman; and Walter W. Weir, secretary-treasurer. Arthur F. Pillsbury was elected as a member of the executive committee. E. P. Speck, W. N. King, Jr., and S. J. Coughran were elected to the nominating committee.

Ohio Section

The Ohio Section meeting was held at the New Idea Division of Avco Mfg. Corp. in Coldwater, Ohio, February 15. A tour of New Idea's manufacturing facilities was made, and a film explaining a machine testing program was shown by the company's engineering department.

Karl D. Butler, farm counselor of New Idea, was the keynote speaker. He spoke on the importance of economics, politics and technology as they relate to the future of U.S. agriculture. Following Mr. Butler's address a panel discussion was held with R. R. Raney, director of engineering, New Idea, as moderator.

Speakers on the panel included: Franklin Smith, operator of Lawn View Stock Farm, who pointed out the farmer's past and present economic problems in changing to a larger and more mechanized farm operation; R. D. Barden, chairman of agricultural engineering, Ohio State University, spoke on the subject of future educational needs for agricultural engineers; Walter M. Carleton, assistant director, AERD, ARS, U.S. Department of Agriculture, said that basic research helps to develop new techniques in growing, harvesting and handling new field crops as well as crops already in general use; R. E. McDaniel, first deputy superintendent of banks for Ohio, commented on the desire of the banking system to provide capital funds for land and equipment financing but also stressed the need of adequate security for such loans; and Blair Williams, assistant general manager for New Idea, stated that although prices paid by farmers for farm equipment have increased, they have not increased as much as farm labor costs.

The next meeting of the Ohio Section will be held May 2 and 3 at Ohio State University. Earl D. Anderson, president of ASAE, will address the group on Saturday, May 3.

Iowa Section

Seventy-three members and guests of the Iowa Section attended the meeting of the Section at Vic's Tally-Ho Restaurant in Des Moines on February 7. A movie on how to build a tire was presented by the Firestone Tire and Rubber Co. after which a tour of the plant was made.

The next Section meeting is scheduled for April 4 and the annual meeting will be held May 16.

Quad City Section

A meeting of the Quad City Section will be held March 14 at the Moline American Legion Club, Moline, Ill. Speakers on the program will include Kenneth K. Barnes of Iowa State College and David J. Milligan

(Continued on page 195)

ASAE MEETINGS CALENDAR

March 14 — QUAD CITY SECTION, Moline American Legion Club, Moline, Ill.

March 28-29—ROCKY MOUNTAIN SECTION, Engineering Center, Colorado State University, Fort Collins, Colo.

March 28-29 — MID-CENTRAL SECTION, Robidoux Hotel, St. Joseph, Mo.

April 2 — CONNECTICUT VALLEY SECTION, University of Connecticut, Storrs, Conn.

April 4 — IOWA SECTION, place not announced.

April 11 — WASHINGTON D. C. SECTION, USDA South Bldg., Washington, D.C.

April 17-18 — ALABAMA SECTION, Whitley Hotel, Montgomery, Ala.

April 18—MICHIGAN SECTION, Howell Boy Scout Camp, Brighton, Mich.

April 24-25—PENNSYLVANIA SECTION, Pennsylvania State University, University Park, Pa.

April 25 — QUAD CITY SECTION, place not announced.

April 25-26 — FLORIDA SECTION, Jacksonville, Fla.

May 2-3 — OHIO SECTION, Ohio State University, Columbus, Ohio

June 22-25 — 51st Annual Meeting, Santa Barbara Campus, University of California, Santa Barbara, Calif.

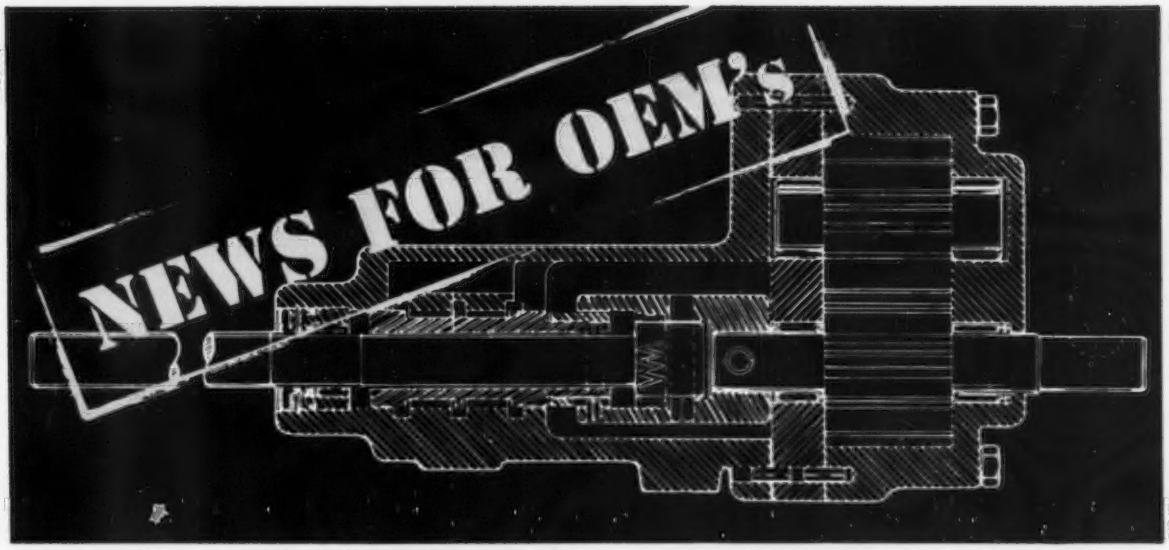
August 25-27—NORTH ATLANTIC SECTION, Guelph, Ontario, Canada.

October 22-25 — PACIFIC NORTHWEST SECTION, Oregon State College, Corvallis, Ore.

NOTE: Information on the above meetings, including copies of programs, etc., will be sent on request to ASAE, St. Joseph, Mich.

Members of a panel discussion held at a meeting of the Ohio Section, February 15, at Coldwater, Ohio. *(Left to right)* R. R. Raney, moderator; Franklin Smith, R. D. Barden, W. M. Carleton, R. E. McDaniel and Blair Williams

Election of officers for the coming year was held during the joint meeting of the Southeast and Southwest Sections of ASAE in Little Rock, Ark., February 3-5. *(Left)* Southeast Section officers are *(left to right)* D. T. Kinard, 2nd vice-chairman; W. J. Liddell, 1st vice-chairman; and T. E. Corley, chairman. A. W. Snell, secretary, not shown. *(Right)* Officers for the Southwest Section are *(left to right)* W. H. Carter, chairman; J. W. McTaggert, vice-chairman; and J. L. Gattis, secretary-treasurer



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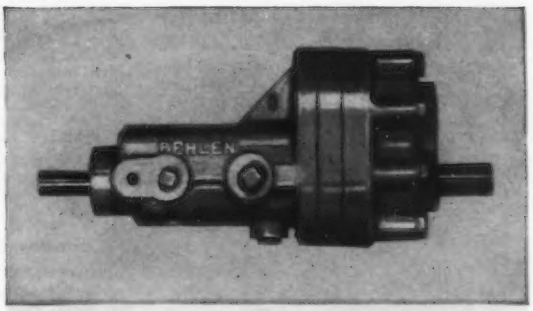

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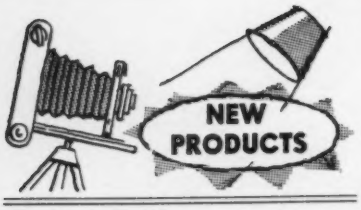


Adds to Baler Line

New Holland Machine Co. has added four new models to its line — the Hayliner 68 wire-tie, Super Hayliner 78 twine-tie,

Super Hayliner 78 wire-tie, and the 98 three-wire baler. The 68 provides a wire-tie baler for the average size farm. The 78 models feature large capacity operation with maneuverability and light weight. The 3-wire baler, the 98 (top view) is especially designed for the commercial man. It is powered by a 30-hp Wisconsin engine and turns out 18 x 22-in. bales from 24 to 48 in. long weighing more than 150 lbs.

(For more facts circle No. 82 on reply card)

New British Tractor

David Brown Tractors Ltd. has announced that it has developed a new tricycle row crop tractor designed to meet the requirements of the North American market. The first consignment to leave the factory is destined for California and Mexico.

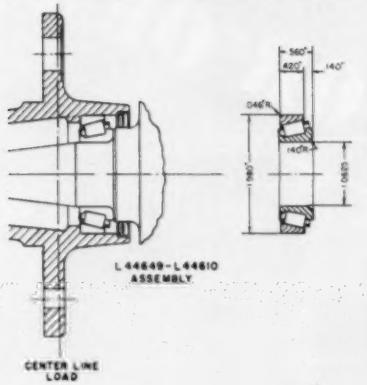
The new Model 903 is particularly intended for row crop cultivation in corn, sugar cane or cotton. Adjustment of the rear wheels can be quickly and easily made in 4-in. steps from 52 to 80 in. The tractor

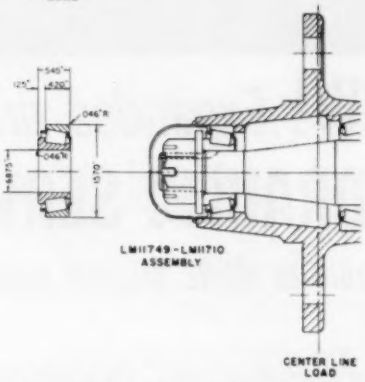
is powered by a four-cylinder, direct-injection diesel engine, has six forward and two reverse speeds and is rated at 40 bhp. Road speeds on the 11 x 38 rear tires (standard) range, at 1850 rpm, from 1.67 to 15 mph. General dimensions of the tractor are: Wheelbase 83 in., turning radius 92 in., overall length 126½ in., minimum overall width 65 in., height to top of steering wheel 67 in.

(For more facts circle No. 79 on reply card)

Low-Cost Bearing Developed

The Timken Roller Bearing Co. has announced two new wheel bearings for use in small automobiles. In addition to automo-



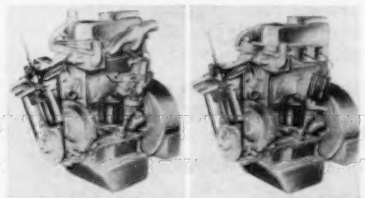


tive applications the company reports that uses for farm machinery, boat trailers and small size conveyors are promising. The larger bearing (upper) has a bore of 1.0625 in., an outside diameter of 1.980 in. and a width of 0.560 in. The smaller bearing (lower) has a bore of 0.6875 in., an outside diameter of 1.570 in. and a width of 0.545 in.

(For more facts circle No. 80 on reply card)

3-Cylinder Engine Series

Hercules Motors Corp. is now manufacturing a new series of 3-cylinder gasoline and diesel engines. This new series of six



models features interchangeability as units and by extensive interchangeability of parts. The cylinder blocks not only are interchangeable between the gasoline and diesel engines of like size, but are so designed that they can be turned end for end and the flywheel housing and gear cover bolted to either end, permitting the power to be taken from either end. In addition, this permits the shifting of manifolds and accessories to either right or left-hand side. The engines are rated at 39 to 51 maximum hp for the gasoline models and 34 to 44 for the diesel models.

(For more facts circle No. 78 on reply card)

Announces New Models

The Oliver Corp. has announced its new line of wheel-type tractors consisting of six models. The model designations, listed in sequence from highest to lowest power ratings, are the 995, 990, 950, 880, 770 and 550. Three kinds of engines (gasoline, diesel and LP-gas) are available. The new 4-5 plow, 6-cylinder 880 model is illustrated.

Features include Power-Booster drive which provides 12 forward speeds, and Power-Traction hitch, designed to deliver more pull power by shifting weight on the tractor's rear wheels. Most powerful in new line is the big, new 995 GM Lugmatic, powered by a 3-cylinder, 2-cycle General Motors diesel engine.

(For more facts circle No. 81 on reply card)

Forage Box for Manure Spreader

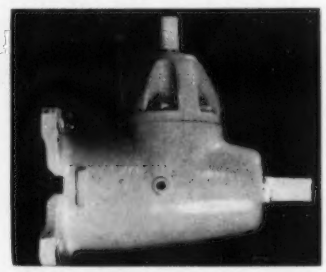
Deere & Co. has announced a new self-unloading forage box attachment for its Model N PTO manure spreader. The at-

tachment unloads chopped material from the side into feed bunks and from the side and rear into blowers, elevator hoppers, trench and bunker silos. It may be ordered with or without bunk-feeding attachment for side delivery.

(For more facts circle No. 84 on reply card)

New Gear Box

Danuser Machine Co. has announced a new precision-made gear box featuring ball bearing construction, ground shafts and heat treated straight tooth bevel gears with one-



to-one ratio. It has a normal rating of 5 hp at 550 rpm. The assembly weighs approximately 25 lb. Full information and engineer's prints are available.

(For more facts circle No. 85 on reply card)

(Continued on page 192)

WHERE POWER STEERING REALLY COUNTS

—making the job easier for the man who rides a tractor

Power steering is every bit as desirable for farm tractors as it is for passenger cars—*and for more and better reasons.*

By taking the tiresome muscle work out of steering, it makes tractor work not only an easier task but a far more efficient operation.

For example, power steering eliminates wheel fight and shock even over the roughest ground; it permits the tractor to be controlled by simply "pointing" where the driver wants it to go.

Also, short turns become an easy, one-hand job even when the tractor is standing still.

Any way you look at it, power steering saves time as well as work, and that's exactly why power steering on farm tractors is destined to be the next step forward in farming efficiency.

Bendix* Power Steering is a performance-proven product designed and engineered by Bendix, foremost producer of power steering and brakes for the automotive industry.

It is used with a conventional steering gear and is adaptable to existing steering linkage, permitting tractor manufacturers to make production-line installations without costly or extensive engineering changes.

Manufacturers interested in adding Bendix Power Steering to their present list of sales features are invited to write for further details to BENDIX PRODUCTS DIVISION, SOUTH BEND, INDIANA. *REG. U.S. PAT. OFF.

Export Sales and Service:
Bendix International Division
205 East 42nd Street, New York 17, N. Y.

Bendix PRODUCTS DIVISION South Bend, IND.

Bendix AVIATION CORPORATION

For more facts circle No. 22 on reply card

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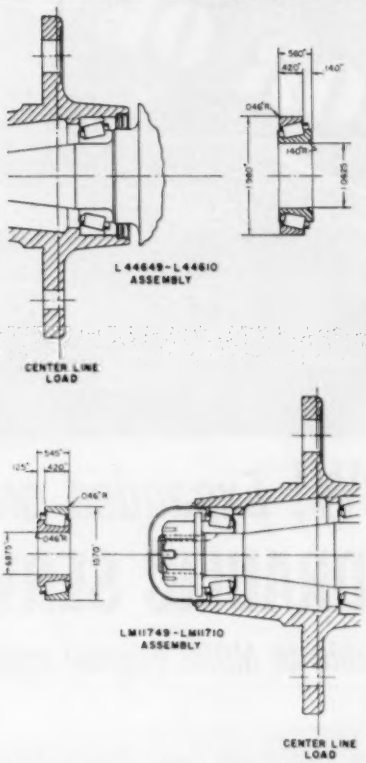

tive applications the company reports that uses for farm machinery, boat trailers and small size conveyors are promising. The larger bearing (upper) has a bore of 1.0625 in., an outside diameter of 1.980 in. and a width of 0.560 in. The smaller bearing (lower) has a bore of 0.6875 in., an outside diameter of 1.570 in. and a width of 0.545 in.

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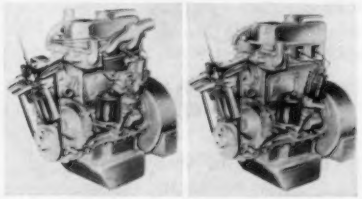

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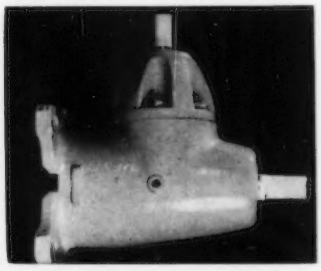

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Bendix AVIATION CORPORATION

For more facts circle No. 22 on reply card

Transport in Agriculture, by G. Bethlendy, J. Heiczman and D. Dertai. Cloth, 6¾ x 9¾ inches, illustrated and indexed, 287 pages. Published by Mezogazuasagi Kiado, Budapest. Prices and purchase information may be obtained by writing G. Bethlendy, 63 Chedoke Ave., Hamilton, Ontario, Canada.

The table of contents of this book has been translated into English and the texts of pictures and graphs are in the process of being translated.

The book is divided into three sections: general considerations, loading and transport equipment, and materials handling. Chapters on loading equipment, loaders and equipment mounted on the tractor or driven by the tractor, road transport equipment, rail transport equipment, transport of liquids, materials handling in buildings, materials handling in the farm yard, materials handling in the field, and long distance transport are included. Also an appendix covers tables comparing the costs and productivity of different materials handling methods and different crops.

Proceedings of the National Conference on Bulk Milk Handling held at Michigan State University in May, 1957, compiled by Carl W. Hall and Donald L. Murray. A copy may be obtained from the Continuing Education Service, Kellogg Center, Michigan State University, East Lansing, Mich., for $2.00. The check or money order should be made payable to Michigan State University.

This book includes over 20 papers covering the various phases of bulk milk handling. These papers present the latest information on the changes and developments from the farm to the plant pertaining to bulk milk handling.

Principles of the Properties of Materials, by Jacob P. Frankel. Cloth, 6 x 9 inches, xiv + 228 pages, illustrated and indexed. Published by McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York 36, N. Y. $6.00.

This is a study of the properties of materials and emphasizes the principles and properties rather than materials. The book is based on a series of lecture notes prepared for sophomore classes in the properties of materials at the Northwestern Technological Institute. Each chapter opens with a synopsis in which the most important principles to be covered are stated. The body of the chapter is devoted to an exposition of the logical derivation and use of these principles. There are questions at the end of each chapter.

It is reported that since the book is intended as an introduction to all fields of engineering, discussions of such matters as magnetic properties and some of the properties of liquids have been omitted.

Artificial Stimulation of Rain, edited by Helmut Weickmann and Waldo Smith. Cloth, 8 x 10 inches, xvi + 427 pages, illustrated and indexed. Published by Pergamon Press, Inc., 122 E. 55th St., New York 22, N. Y. $15.00.

This book contains the proceedings of the first conference on the physics of cloud and precipitation particles which was held at Woods Hole Oceanographic Institution, Mass. The subject of cloud physics is one which is increasing in importance, and within this field the branch relating to cloud and precipitation particles has been an active field of research. This volume, containing papers presented at the conference, reflects the latest ideas and developments and provides invaluable information for scientists in the many aspects of research allied to cloud physics, and to all concerned with cloud modification and weather control.

• Our complete engineering, production, distribution and service facilities are devoted to the single-minded task of supplying engines to match the critical performance demands of all types of modern mechanized equipment within a 3 to 56 hp. range.

Wisconsin specialization extends to full-scale concentration on 4-CYCLE HEAVY-DUTY AIR-COOLED ENGINES . . . backed by extensive and diversified experience in the production of engines dating back to 1909.

When you specify "WISCONSIN" you definitely get a *better engine* . . . an engine with a basic load-holding High Torque factor; an engine in which almost fifty years of exclusive engine-building experience has paid off in terms of heavy-duty serviceability under all types of operating conditions, in every equipment category; a universally known engine that "has everything" that know-how and a quality-conscious production policy can provide . . . backed by a world-wide sales and service organization in 90 countries.

This, we believe, is what you are looking for as original power components for *your* equipment. Let's get together. Engine Bulletin S-223 is yours for the asking.

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MILWAUKEE 46, WISCONSIN

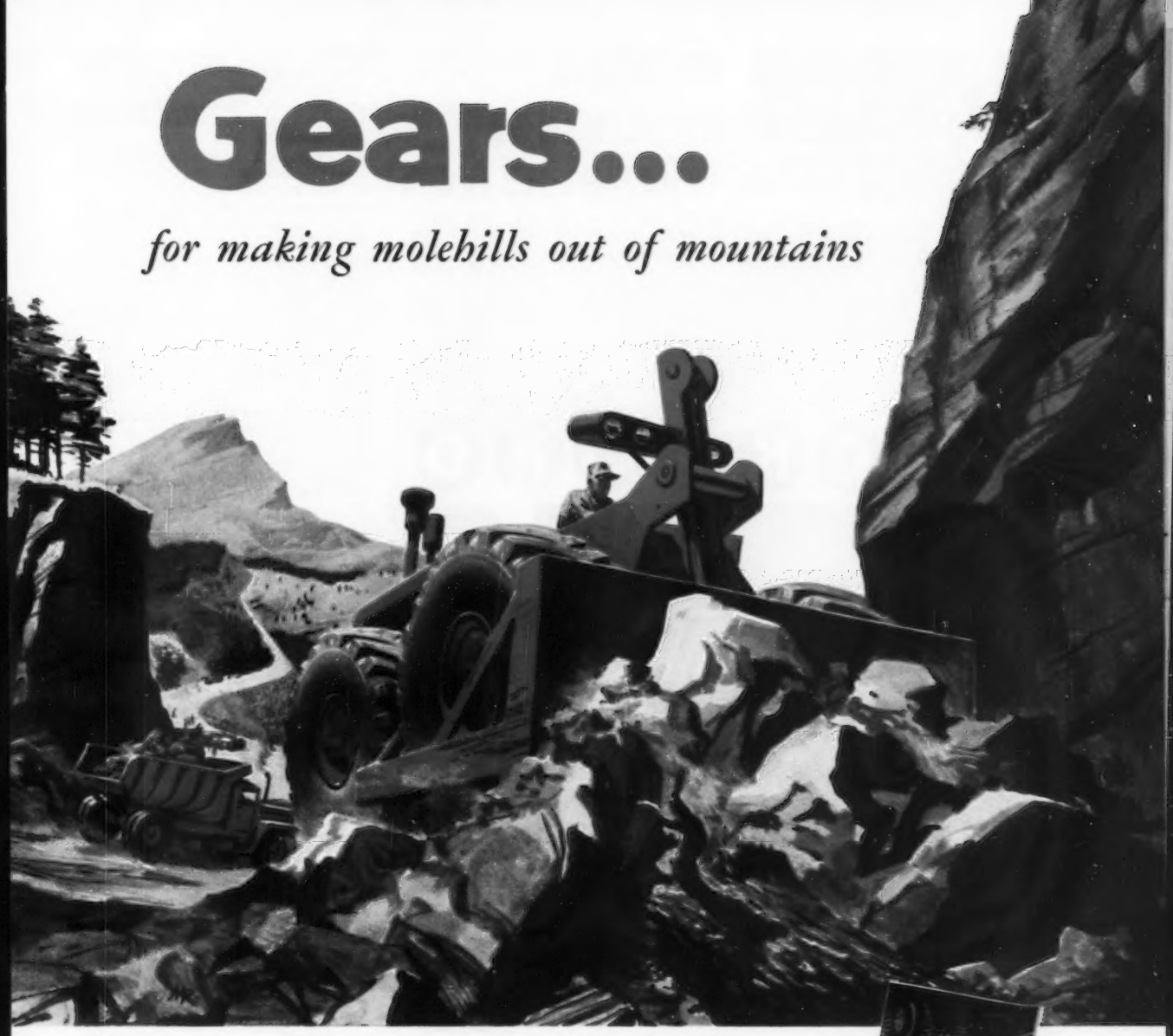
The following bulletins have been released recently. Copies may be obtained by writing to author or institution listed with each.

Mow Hay Drying, Spring, 1957. Central Vermont Public Service Corp., 77 Grove St., Rutland, Vt.

Progress Report of the Farm Electric Utilization Project (March, 1957), by K. L. McFate, Agricultural Engineering Dept., University of Missouri, Columbia, Mo.

Gears...

for making molehills out of mountains



It is hard to imagine worse working conditions, and that is the very reason why the manufacturers of so many kinds of road building equipment install "Double Diamond" gears. Wherever the going is especially rough, wherever gears must give uninterrupted service on harsh, time-table schedules, you'll find our gears at work.

For low installed cost, for true operating economy and performance, and for buckling down to the hardest kind of service—nothing beats "Double Diamond."

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RICHMOND, INDIANA

GEARS FOR AUTOMOTIVE, FARM EQUIPMENT AND GENERAL INDUSTRIAL APPLICATIONS
GEAR-MAKERS TO LEADING MANUFACTURERS

For more facts circle No. 24 on reply card

The following is a list of recent applicants for membership in the American Society of Agricultural Engineers. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Augsburger, Norman D.—Sales mgr., Acme Eng. & Mfg. Corp., P.O. Box 1203, Muskogee, Okla.

Bayer, Burke B. — Secy.-treas., gen. mgr., Bayer Construction Co., Inc., 509 Yuma St., Manhattan, Kans.

Berry, William H.—Staff asst., Tech. Review Staff, USDI. (Mail) 2008 N. Daniel St., Apt. 4, Arlington, Va.

Besemer, John S.—Sales engr., New Departure Div., General Motors Corp., 7-122 General Motors Bldg., 3044 W. Grand Blvd., Detroit 2, Mich.

Bice, James F.—Des. engr., J. I. Case Co., 2500 Des Moines Ave., Burlington, Ia.

Booth, Bert E. — Agr. engr., SCS, USDA. (Mail) P.O. Box 225, Harlingen, Texas

Brownscombe, Ralph H. — Drainage engr., SCS, USDA. (Mail) 1680 N.W. 1st St., Gresham, Ore.

Bullock, J. Charles — District mgr., Link-Belt Co., 1614½ 5th Ave., Moline, Ill.

Buras, Nathan — Drainage district engr., Israel Water Planning Co., Ltd., Haifa, Israel. (Mail) Irrigation and Soils Dept., Univ. of Calif., Los Angeles 24, Calif.

Cresswell, Robert E.—Standards engr., John Deere Des Moines Works. (Mail) 5928 Cottage Dr., Des Moines, Ia.

Dietz, Donald C.—Farm spec., Pennsylvania Power & Light Co., 19th and Brookwood Sts., Harrisburg, Pa.

Haley, William B. — Sales engr., Chicago Rawhide Mfg. Co. (Mail) 725 Union Arcade, Davenport, Ia.

Hendrickson, Miner H. — Draftsman-engr., Wood Conversion Co., First National Bank Bldg., St. Paul, Minn.

Hocking, Thomas A. — Des. engr., International Harvester Co., East Moline Works, East Moline, Ill.

Hudgins, Arvin Q. — Eng. trainee, John Deere Waterloo Tractor Works. (Mail) 205 E. 6th St., Apt. 7, Waterloo, Ia.

Jaber, Jalal H.—Head, Agricultural Division, P. W. D. Kuwait, Arabia (Persian Gulf)

Johndreau, Clarence N. — Agr. field rep., Portland Cement Assn. (Mail) 2317 Baker St., Ames, Ia.

Johnson, Arthur C.—Proj. engr., Superior Separator Co., Farmhand Div. (Mail) 6900 Upton Ave. S., Minneapolis 23, Minn.

Johnson, Kenneth D.—Test engr., International Harvester Co. (Mail) 830 1st Ave., East Moline, Ill.

Knepper, Larimer J.—Draftsman, New Holland Machine Co. (Mail) Churchtown, Pa.

Lakin, Lewis G.—Engr., A. Lakin & Sons, Inc., 2036 N. Dominick, Chicago, Ill.

Lever, Norman G. — Regional sales mgr., Dayton Rubber Co., 400 W. Madison, Chicago, Ill.

Meacham, Vernon H.—Principal instr. of surveying, Calif. State Polytechnic College, San Luis Obispo, Calif.

Mora R., Jose A. — Charge of soils div., agronomy dept., Servicio Tecnico Agricola de Nicaragua. (Mail) P.O. Box 215, Managua, Nicaragua

Norman, Grover C.—Farm mechanics spec., State Dept. of Education, Tallahassee, Fla.

Peloch, Harry — Civil engr., Saskatchewan Dept. of Agr., Conservation and Development Branch. (Mail) Weirdale, Sask., Canada

Reich, Brian M.—Asst. and regional engr., Dept. of Agriculture, Pte. Bag 1021, Pietermaritzburg, South Africa

Sartor, William T. Jr.—Engr., U.S. Bureau of Reclamation. (Mail) P.O. Box 24, Alto, La.

Signor, Donald C. — Grad. res. asst., agr. eng. dept., Univ. of Nebraska. (Mail) 2957 Holdrege, Lincoln, Nebr.

Van Allen, Francis V.—Supervisor, International Harvester Co., P.O. Box 270, Melrose Park, Ill.

Van Rest, David J.—Grad. res. asst., agr. eng. dept., Univ. of Calif. (Mail) 237 1st St., Davis, Calif.

Vieira, Jose A. L. — Agr. engr., Seccao de Fomento Agricola, Ministry of Agriculture, Sao Paulo, Brazil, S. A. (Mail) 963 Peach St., San Luis Obispo, Calif.

Wilde, Douglas H.—Agr. spec., Saskatchewan Power Corp., Regina, Saskatchewan, Canada

Transfer of Membership

Goldoftas, Tobi—Des. engr., International Harvester Co. (Mail) 455 Shabbona Drive, Park Forest, Ill. (Associate Member to Member)

Larsen, Dorrell C.—Ext. irrigationist, Agr. Ext. Service, Univ. of Idaho, 317½ N. 8th St., Boise, Idaho. (Associate Member to Member)

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Keep Heavy-Duty Machines
400% More Hours ON the Job
90% Less Time IN the Shop

MORLIFE clutches serve from four to ten times longer than previous types of friction clutches using organic facing materials. *Adjustments and plate replacements have been reduced to one-tenth those required by previous clutches.* The longer on-the-job hours and increased pay loads which MORLIFE clutches make possible furnish a competitive advantage for machines in which these NEW clutches are used. Increased clutch life results in decreased operation cost of vehicles or equipment.

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Small Spring Loaded

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Oil or Dry Multiple Disc

Heavy Duty Over Center

Power Take-Offs

Speed Reducers

CLUTCHES

Patterson, John A.—Sr. agr. engr., Ministry of Agriculture, Khartoum, Sudan. (Associate Member to Member)

Shelton, Curtis H. — Asst. prof., agr. eng. dept., Univ. of Tenn. (Mail) 516 Moody Ave., Knoxville, Tenn. (Associate Member to Member)

Stiles, David N.—Farm sales mgr., Connecticut Light & Power Co. (Mail) 747 Mountain Road, Cheshire, Conn. (Affiliate to Member)

STUDENT TRANSFERS

Besson, Luis A. — Student, Oklahoma State University (Mail) Pasaje La Esmeralda. No. 1, San Jose, Caracas, Venezuela, S.A.

Blinne, David Lee — Student, University of Missouri (Mail) 619 W. Essex, Kirkwood, Mo.

Budiselich, Eugene T. — Student, Washington State College (Mail) 209 E. McKenzie, Pullman, Wash.

De Sambourg, Warren E.—Student, Louisiana State University (Mail) 3811 Sherwood Drive, Baton Rouge 5, La.

Dominick, Max D.—Student, Oklahoma State University (Mail) P.O. Box 53, Hartshorne, Okla.

Echaverry, Silvio—Student, Oklahoma State University (Mail) Siriamba, Nicaragua

Gebhardt, Maurice R.—Student, University of Missouri (Mail) Agr. Eng. Dept., University of Missouri, Columbia, Mo.

Graham, Walker W. — Student, Louisiana State University (Mail) Lee Holland Implement Co., West Memphis, Ark.

Grasch, Gerald D.—Student, Kansas State College (Mail) Cawker City, Kans.

Lassiter, Charles D. — Student, Louisiana State University (Mail) P.O. Box 6431, Baton Rouge 3, La.

Mathis, Melvin L. — Student, Washington State College (Mail) P.O. Box 709, Okanogan, Wash.

Munson, Edward D. — Student, University of Missouri (Mail) R.R. 3, Centralia, Mo.

Odell, John G. — Student, Washington State College (Mail) R.R. 1, Davenport, Wash.

Parker, Jimmy J. — Student, Texas Technological College (Mail) 2122 B-Duke, Lubbock, Texas.

Patel, Nagarbhai G.—Student, University of Nebraska (Mail) Agr. Eng. Dept., Univ. of Nebraska, Lincoln 1, Nebr.

Patterson, William B. — Student, Kansas State College (Mail) Niotaze, Kans.

Poston, Carl W. — Student, Kansas State College (Mail) Rose Hill, Kans.

Rattan, Douglas C. — Student, Texas Technological College (Mail) Agr. Eng. Dept., Texas Technological College, Lubbock, Texas

Reinbold, Mark F. — Student, Washington State College (Mail) 1503 Lower Drive, Pullman, Wash.

Rowen, Eugene L. — Student, South Dakota State College (Mail) St. Lawrence, S.D.

Schooley, William A. Jr. — Student, Pennsylvania State University (Mail) Laurelton, Pa.

Schultz, Charles J. — Student, University of California (Mail) 515 E. 11th, Davis, Calif.

Schultz, George R. — Student, University of Nebraska (Mail) Ponca, Nebr.

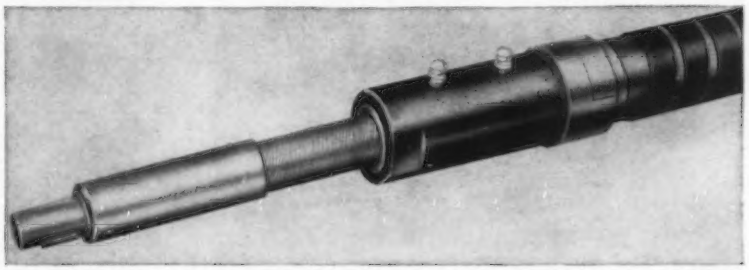
Shanholtz, Vernon O. — Student, West Virginia University (Mail) Intermont, W. Va.

Simpson, John B. — Student, Washington State College (Mail) St. John, Wash.

Smith, Calvin—Student, Michigan State University (Mail) R.R. 1, Portland, Mich.

(Continued on page 195)

HOW TO SELECT FLEXIBLE SHAFTING FOR POWER DRIVE APPLICATIONS



1¼-inch STOW Power Drive flexible shaft with core assembly pulled out of casing.

For Power Drive applications, the following factors must be considered:

1. Torque (Lb. In.) to be transmitted. (The starting torque should be used in making selections).

2. Operating Speeds (RPM)—If the maximum speed is higher than the rated speed, torque ratings in the table below do not apply. To find the torque capacity for flexible shafts operating at speeds higher than the rated speeds, multiply the maximum dynamic torque capacity by the rated speed, and then divide by the operating speed. (See example).

3. Operating Radius—In making the selection from the table below, the radius of the smallest bend in the flexible shaft should be used.

Ratings — The ratings for flexible shafts shown in the table below apply under the following conditions:

1. When the flexible shaft is adequately supported by clamps along its length. (For unsupported shafts, multiply the calculated torque by a safety factor of 1.6—see example below)

2. When the flexible shaft is operated in the wind-up direction, which tends to tighten the outer layer of wires. (Flexible shafts operated in the unwind direction will transmit only about 60% of the rated torque).

3. When the flexible shaft is in continuous operation. Note: **the ratings are based on temperature rise. When the operation is intermittent, the ratings in the table may be exceeded. Consult Stow Engineers for specific recommendations.**

RATED SPEED R.P.M.	MAXIMUM DYNAMIC TORQUE CAPACITY (LB. IN.) STRAIGHT AND CURVED SHAFTS RADIUS OF CURVATURE IN INCHES									Wgt./ C. Ft.	Core Dia.	Core No. and Type	Shaft Size
	50 to Strgt.	25	20	15	12	10	8	6	5				
4,500	2.4	2.2	2.0	2.0	1.92	1.9	1.7	1.5	1.25	3.0	.124/.128	2049 MH	13
3,800	7 0	6.4	6.0	5.8	5.4	5.0	4.6	3.6	2.0	4.5	.148/.152	2081 MH	15
2,900	9.4	8.6	8.0	7.6	7.0	6.6	6.0	4.8	3.4	7.0	.185/.189	5108 MH	19
2,500	22.0	20.0	18.8	17.6	16.0	15.0	12.6	10.8	9.0	12.5	.247/.252	8924 MH	25
1,800	30.0	28.0	26.4	25.0	23.0	21.0	18.0	14.0		20.0	.308/.313	8925 MH	31
1,800	33.8	31.5	29.7	28.1	25.9	23.6	20.2	15.8		20.0	.308/.313	8969 T	31
1,800	36.0	33.0	31.6	30.0	28.0	26.0	22.0	18.0	11.0	21.0	.324/.329	2034 A	31
1,500	80.0	66.0	63.0	58.0	51.0	46.0	37.0	22.0		28.5	.368/.374	2035 A	38
1,500	60.0	54.0	50.0	46.0	42.0	38.0	30.0	24.0		29.0	.387/.393	8970 MH	40
1,500	90.0	81.0	75.0	69.0	63.0	57.0	45.0	36.0		29.0	.387/.393	8971 T	40
1,150	136.0	110.0	104.0	94.0	80.0	72.0	56.0			50.5	.497/.503	8999 A	50
1,150	148	124	110	92	72	56				53.5	.505/.511	6940 T	50
900	248	200	176	124	84					78.5	.610/.618	6997 T	63
900	220	204	192	180	152	130				80.5	.630/.638	7731 A	63
750	340	224	156	76						117	.747/.753	2056 T	75
600	760	520	420							205	.998/1.004	2057 T	100
440	1,500	720								343	1.298/1.304	2058 T	125

EXAMPLE — How to use the table:

The problem is to transmit ½ H.P. at 1700 RPM through an unsupported flexible shaft in a 25" radius, estimated starting torque 150% of normal operating torque.

1. Calc. Torque (lb. in.)—

$$\frac{HP \times 63000}{RPM} = \frac{.5 \times 63000}{1700} = 18.5$$

2. Correction factor for starting torque 1.5 x 18.5=27.75

3. Correction factor for unsupported shaft 27.75 x 1.6 = 44.4 lb. in.

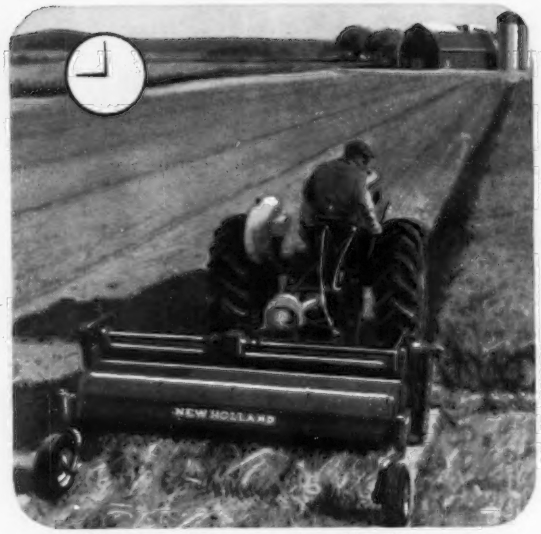
4. Refer to Table No. 1. Read downward in column under 25" radius until you find a core having a rating of at least 44.4 lb. in. In this case we find that core No. 8970 is rated 54 lb. in. at 1500 RPM. Since the given speed is 1700 RPM, multiply 54 by 1500 and divide by 1700.54 ×1500 ÷ 1700 = 47.6 lb. in. (rated torque at 1700 RPM). Therefore, Core No. 8970 is correct.

STOW

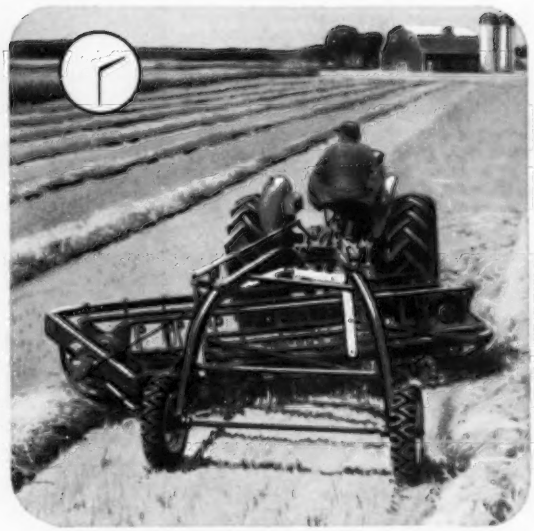
For Engineering Bulletin No. 570 and a free torque calculator, write

STOW MANUFACTURING COMPANY

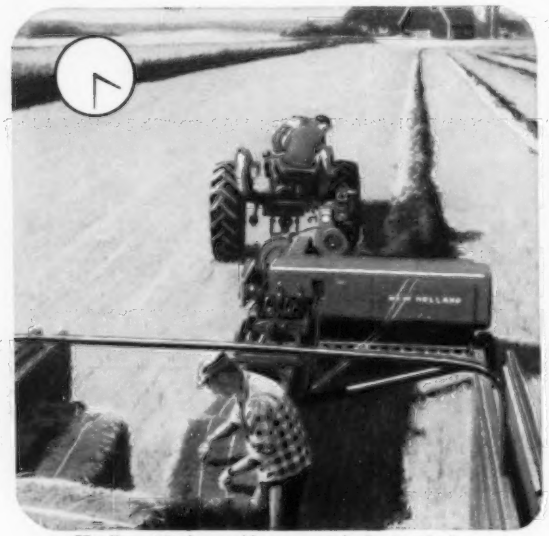
39 Shear Street • Binghamton, New York



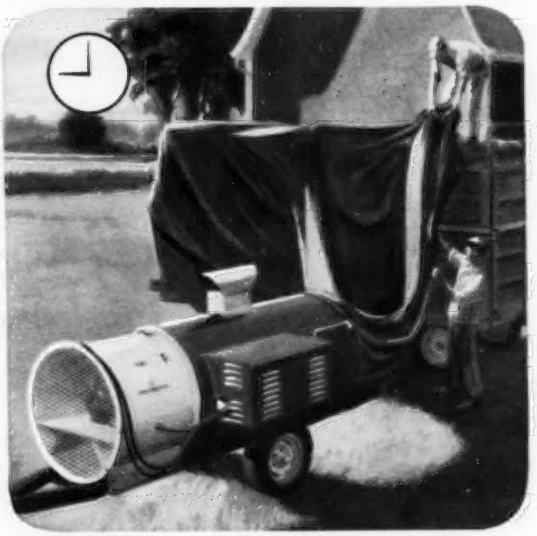
Mower-crusher gets curing off to fast start



Rolabar rake forms fast-drying windrows



Hayliner 68 ties uniform, quick-drying bales



Crop dryer and wagons dry 10 tons overnight

Hay-in-a-Day!

New haying system reduces farmers' dependence on weather . . . saves nutrients for top-quality hay.

Both of these requirements are met by New Holland's Hay-in-a-Day system.

Hay-in-a-Day is made possible by the use of a team of machines that work fast, promote quick drying and handle hay gently. It helps a farmer move hay from standing crop to storage in as little as 24 hours.

Mowing and crushing in one early-morning operation makes it possible to rake by early afternoon. Baling begins in the mid-afternoon. Bales are stacked directly on crop drying wagons which are then hitched to an automatic crop dryer—which overnight brings the hay down to the proper moisture content for storage.

The result is green, leafy hay rich in nutrients—the kind of hay that can reduce or even eliminate costly supplemental feeding. For complete details, write for our *free* Hay-in-a-Day booklet. New Holland Machine Company Division of Sperry Rand Corporation, New Holland, Pennsylvania.

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☐ I am an ASAE member and suggest that membership information, including application form, be sent to the name and address below. I can supply names of _____ more prospective members. My name is _____

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6	16	26	36	46	56	66	76	86	96
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5	15	25	35	45	55	65	75	85	95
6	16	26	36	46	56	66	76	86	96
7	17	27	37	47	57	67	77	87	97
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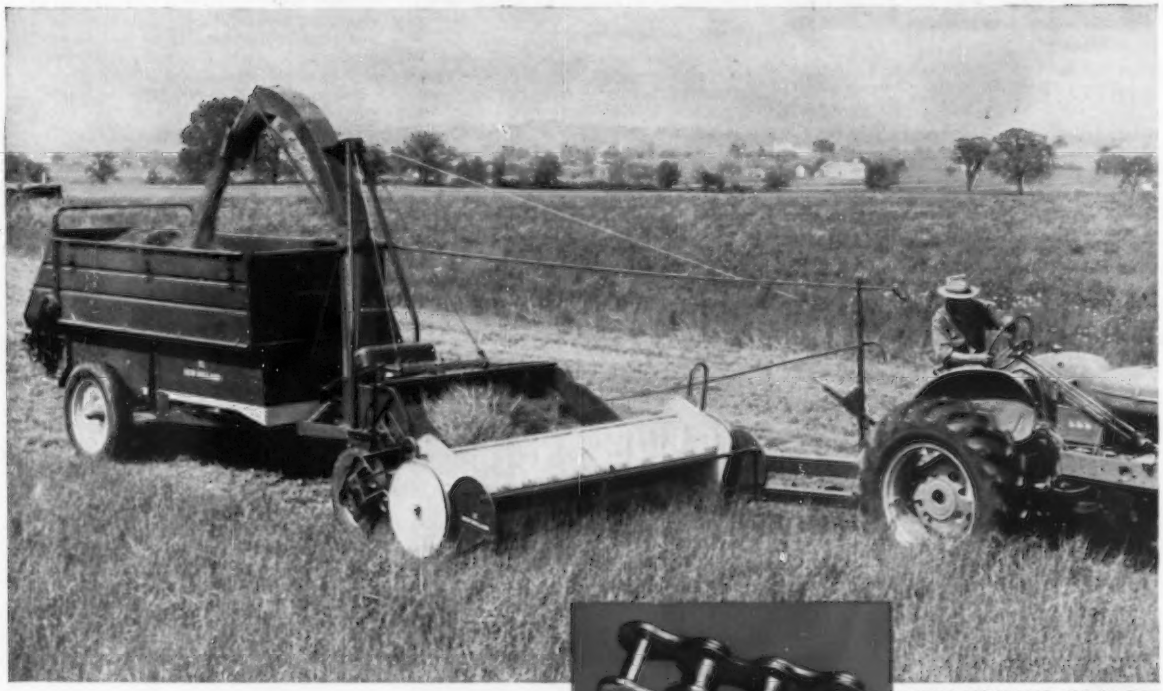
The good name of your machine is LINK-BELT's first consideration . . . TRADE MARK . . . and quality should be your first consideration in the chain you buy



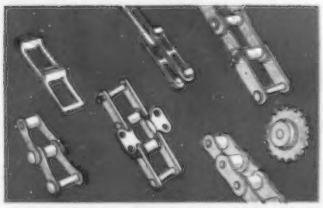
NEW HOLLAND FORAGE HARVESTER and wagon which use Link-Belt "AG" chain, roller chain, steel detachable Link-Belt and sprockets.

Is the chain you use as good as the machine you make?

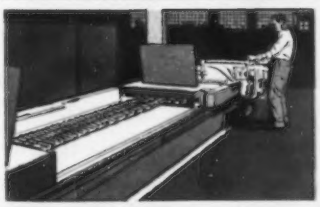
Here's how LINK-BELT matches drive and conveying chain to the field requirements of your equipment

THE Link-Belt double-arrow trademark >——< on chain means that each link in every length conforms to rigid quality and uniformity specifications. And it's your assurance that the drive or conveyor chain specified will maintain rated performance and efficiency on your machine.

From the world's largest chain plant, Link-Belt offers you the economies of mass-production . . . represents a ready source for all your chain and sprocket needs. For prompt service, call your nearby Link-Belt office. 14,750



COMPLETE LINE of agricultural chains, sprocket wheels and attachments permits cost-saving specialization — offers right chain for all conveyor and drive needs.



ACCURATE MANUFACTURE AND CONTINUOUS INSPECTION with modern, specialized machines allow economies of large-scale production. Extensive facilities provide ample capacity to meet your production schedules.

LABORATORY CONTROL assures you that each chain meets rigid uniformity specifications. Our modern laboratory continuously explores new refinements to increase chain life.

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CHAINS AND SPROCKETS

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville (Sydney), N.S.W.; South Africa, Springs. Representatives Throughout the World.

For more facts circle No. 25 on reply card

MANUFACTURERS' LITERATURE

Combines

Allis-Chalmers Mfg. Co. — A 16-page catalog (TL-1788) which describes the "Gleaner-Baldwin" combine manufactured by the company. Features of the combine include center-line design, operator comfort and convenience, longer separating area, exclusive two-fan cleaning, etc. The catalog also contains a specifications chart.

(For more facts circle No. 64 on reply card)

Roller Chain Prices

Diamond Chain Company, Inc.—Bulletin No. 507 includes pricing information on standard attachments for standard and double pitch roller chains. These attachments and suggestions as to how they can be used are illustrated.

(For more facts circle No. 65 on reply card)

Lubrication Equipment

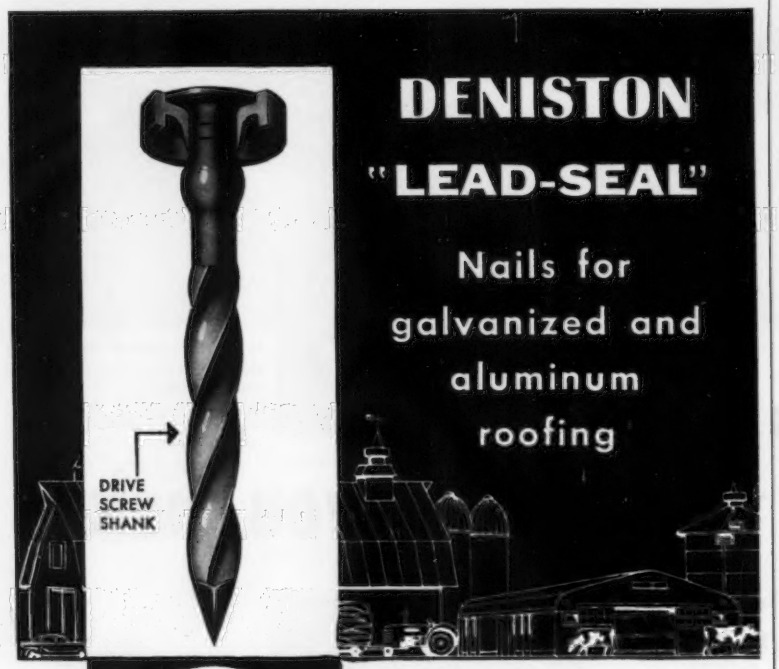
Lincoln Engineering Co. — Catalog 92 showing the complete line of the company's lubricant application equipment with dimension drawings. Also presented are the features of lubrication fittings, grease guns, centralized power lubrication systems and accessories.

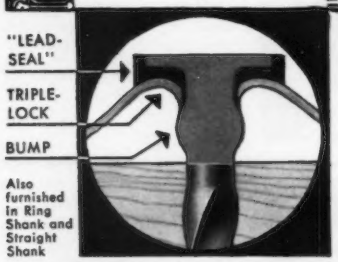
(For more facts circle No. 66 on reply card)

Hydraulic Hose Fittings

Parker-Hannifin Corp.—Catalog 4440 describes reusable fittings for use with rubber covered wire braided hydraulic hose in sizes from 3/16 through 1 1/8 in. inside diameter.

(For more facts circle No. 67 on reply card)





All Deniston nails can be shipped in either 50 lb. or 100 lb. sturdy 3-ply corrugated color-board cartons with hand grips for easy handling.

Deniston's quality "Lead-Seal" metal roofing nail with "Triple-Lock" is heavily zinc-coated for protection against rust. It insures a permanent seal through which no moisture can penetrate, because when the hammer strikes the nail (not the lead), the "bump" and the lead are forced through the metal sheet, the sheet springs back over the "bump"—this solidly locks together the nail, lead and sheet.

Descriptive literature on Deniston "Lead-Seal" nails will be sent immediately upon request.

31 Years of Quality Nails

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DENISTON Lead-head ROOFING NAILS TRADE MARK

For more facts circle No. 27 on reply card

Mechanical Power Transmission and Conveying Machinery

Chain Belt Co.—Catalog 610 contains descriptions, specifications, application information and selection data on the company's products for power transmission, conveying and elevating service.

(For more facts circle No. 68 on reply card)

Irrigation Pipe

Johns-Manville — An 8-page illustrated brochure describing the company's line of Transite irrigation pipe. Also discussed are sprinkler system irrigation, pump-back systems in waste-water recovery and source-to-high-point water lines and pipe for general farm service.

(For more facts circle No. 69 on reply card)

Insulation Booklet

Owens-Corning Fiberglas Corp.—A 12-page booklet which describes and illustrates how insulation can improve the efficiency of dairy buildings, poultry houses, pump houses, cold storage buildings, farm shops, lambing barns, farrowing houses, maternity quarters, specialty buildings, the farmhouse and residences.

(For more facts circle No. 70 on reply card)

Rivet Fasteners

Hi-Shear Rivet Tool Co.—A 4-page brochure on a new lock-type rivet fastener. The brochure describes the advantages, gives technical details of the fastener and discusses tooling.

(For more facts circle No. 71 on reply card)

Engine Controls

Cole-Hersee Co. — An 8-page catalog (Form D-227) of displays and proven merchandisers which covers the field of switches, connectors, voltage reducers, voltage control units, plugs, sockets, protective devices and knobs for automotive, truck, trailer, bus, marine, farm, earth-mover and industrial equipment.

(For more facts circle No. 72 on reply card)

Conservation Needs

Caterpillar Tractor Co.—A 12-page booklet telling of the conservation needs of the United States and the people who do such work. Irrigation practices, land clearing, land forming, deep tillage and general construction methods are outlined and illustrated.

(For more facts circle No. 73 on reply card)

Timing Belt Drives

Morse Chain Co.—Catalog TB-58 covers the following Timing belt pitches, 1/5, 3/8, 1/2, 7/8, and 1 1/4 in. It contains information on selection, installation and use of these drives.

(For more facts circle No. 74 on reply card)

Small Engine Ignition Parts

Wells Mfg. Corp. — A 28-page catalog 58SE with buyers guide index, illustrations of ignition parts and various engines and magnetos, with specifications and application guide for power lawn mowers, outboards, chain saws, scooters, dusters, and other small engine equipment.

(For more facts circle No. 75 on reply card)

Bean Windrower

Innes Co.—A 4-page leaflet illustrating the company's bean windrower featuring three models. Mechanical and construction features are described in detail.

(For more facts circle No. 76 on reply card)

Loaders, Shovels, Backhoes

Henry Mfg. Co. — A folder picturing and describing the company's new line of loaders, tractor shovels, and backhoes. Specification charts are included.

(For more facts circle No. 77 on reply card)

NEW IDEA No. 400 pull-type parallel bar rake. Tested on the torture track, proved on farms.

GREEN: *the color of cash . . . and top quality hay*

There's a big cash difference in feeding costs between fine hay and poor. Quality hay means better feeding, lower production costs for milk and beef. When hay is poor, you must pay more for protein and mineral supplements.

What makes green, leafy, nutrient-rich hay? The sun and the showers have a lot to do with it—and these no farmer can completely control. But the right machines play a vital part, too — and here a man can stack the odds in his favor.

That's the job of NEW IDEA engineers. To help take the gamble out of hay-making. To provide farmers with precision tools that cut, cure and store hay, rich in protein and vitamins, appetizing to livestock.

NEW IDEA mowers, for example. They cut clean on sharp turns, shear easily through the thickest stands. Like all NEW IDEA machines, they're built a little stronger than necessary.

NEW IDEA rakes are designed to turn tender, high-protein leaves into the center of the windrow where they cure away from the searing sun. Hard-to-cure stems are turned outward for faster curing. More of the feed value in the hay gets to the barn and livestock.

Write us for free illustrated literature. The facts, we are sure, will convince you that NEW IDEA helps the farmer "make hay" in more ways than one.

NEW IDEA FARM EQUIPMENT CO. • Division Arco Distributing Corp., Coldwater, Ohio

For more facts circle No. 28 on reply card

You Can't Beat
GALVANIZED
Roofing & Siding

FOR BEST VALUE, buy *Grade-Marked* sheets, which show weight of zinc coating. And for longer, stronger service, specify heavy-coated roofing and siding such as the "Seal of Quality" . . . With *galvanized* sheets, you get the *strength* of steel, the *protection* of zinc. Preferred by thousands of users. Proved by time itself. Feature by feature, they're your *best buy*. Check and compare with any other material!

ZINC INSTITUTE 2 OZ. COATING SEAL OF QUALITY

	GALVANIZED SHEETS	ANY OTHER MATERIAL
STRUCTURAL STRENGTH and rigidity; withstand rough treatment	YES	
YEARS OF RUST-FREE SERVICE; little or no upkeep problems	YES	
EASIEST TO HANDLE, lay and nail; stay put, hold at nail-holes	YES	
LIGHTNING PROTECTION, fireproof, ratproof, pleasing appearance	YES	
LOW COST ALL THE WAY, to buy, to apply and thru the years	YES	

FREE! "DO-IT-YOURSELF" MANUALS

Write: AMERICAN ZINC INSTITUTE
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☐ Facts About Galvanized Sheets
☐ How To Lay Galvanized Sheets
☐ Metallic Zinc Paint for Metal Surfaces

NAME_____
ADDRESS_____
CITY & STATE_____

For more facts circle No. 34 on reply card

. . . New Products

(Continued from page 180)

5-Plow Tractor

Allis-Chalmers Mfg. Co. has announced a new Model D-17 tractor designed to pull a 5-bottom moldboard plow. This low-line,

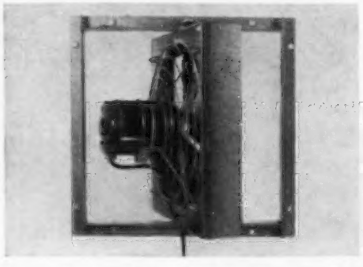
high-clearance tractor is available with choice of two new engines (gasoline or diesel) each rated over 50 hp.

Weight is approximately 5,280 lb with gasoline engine, and wheelbase is 93 in. The diesel-powered tractor weighs approximately 5,680 lb and wheelbase is 95¾ in. A power control system, called Power Director, permits on-the-go shifting to high or low range, providing 8 forward speeds up to 14⅖ mph. The system includes a live power take-off, and continuous operating hydraulic pump. With the Power Director, forward travel speeds reportedly can be increased by 50 percent or reduced by 30 percent, without gear shifting.

(For more facts circle No. 86 on reply card)

Swivel Fan

Aerovent Fan and Equipment, Inc. has developed a swivel-type, two-way poultry house fan that exhausts in the winter and



forces fresh air in during summer. The unit is housed in a stationary steel angle frame. By pulling a pin, the inner panel turns 180 deg clockwise for winter use. The pin locks it in place. To reverse the unit, the fan turns counter-clockwise only, thus keeping the cord from twisting.

(For more facts circle No. 87 on reply card)

PTO-Driven Electrall

International Harvester Co. has announced that its Electrall generator, previously designed as a V-belt driven, side-

mounted unit for larger tractors, is now available for PTO use with any make of 2-plow or larger tractor. This mobile power station now is being made as an attached or trailing model for use with 25-hp or larger tractors with ASAE standard, 1⅜-in. diameter, 540-rpm power take-off.

The PTO-driven model produces the same alternating current obtained from power company high lines — 115 and 220 volts, 60-cycle, single-phase power. It also provides 208-volt, 3-phase, 60-cycle, alternating current for 3-phase motors up to 10 hp.

(For more facts circle No. 88 on reply card)

Expands Bearing Line

Nice Ball Bearing Co. has announced a new addition to its bearing line through its appointment as manufacturer of Heim-

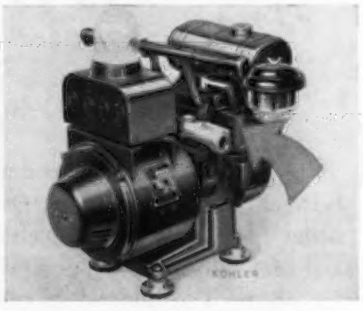
Unibal ball bearings. These bearings feature solid inner and outer raceways and a full complement of balls, without the use of any loading slot or split race to admit the balls to the bearing.

Bearings will be available in single row radial, double row radial, flanged or snap ring types, with or without extended inner races, with or without shields or seals and in a wide range of widths and diameters.

(For more facts circle No. 89 on reply card)

Idling Device for Electric Plants

Kohler Co. has announced an idling device for three portable models of electric plants which reduces the speed of the plants when operating under no-load conditions.



The device keeps the plant idling at 1400 rpm until load is applied. Speed is then increased to the regular operating rate of 3600 rpm and drops again to 1400 rpm when load is removed. It is available either installed at the factory or as a kit for field installation.

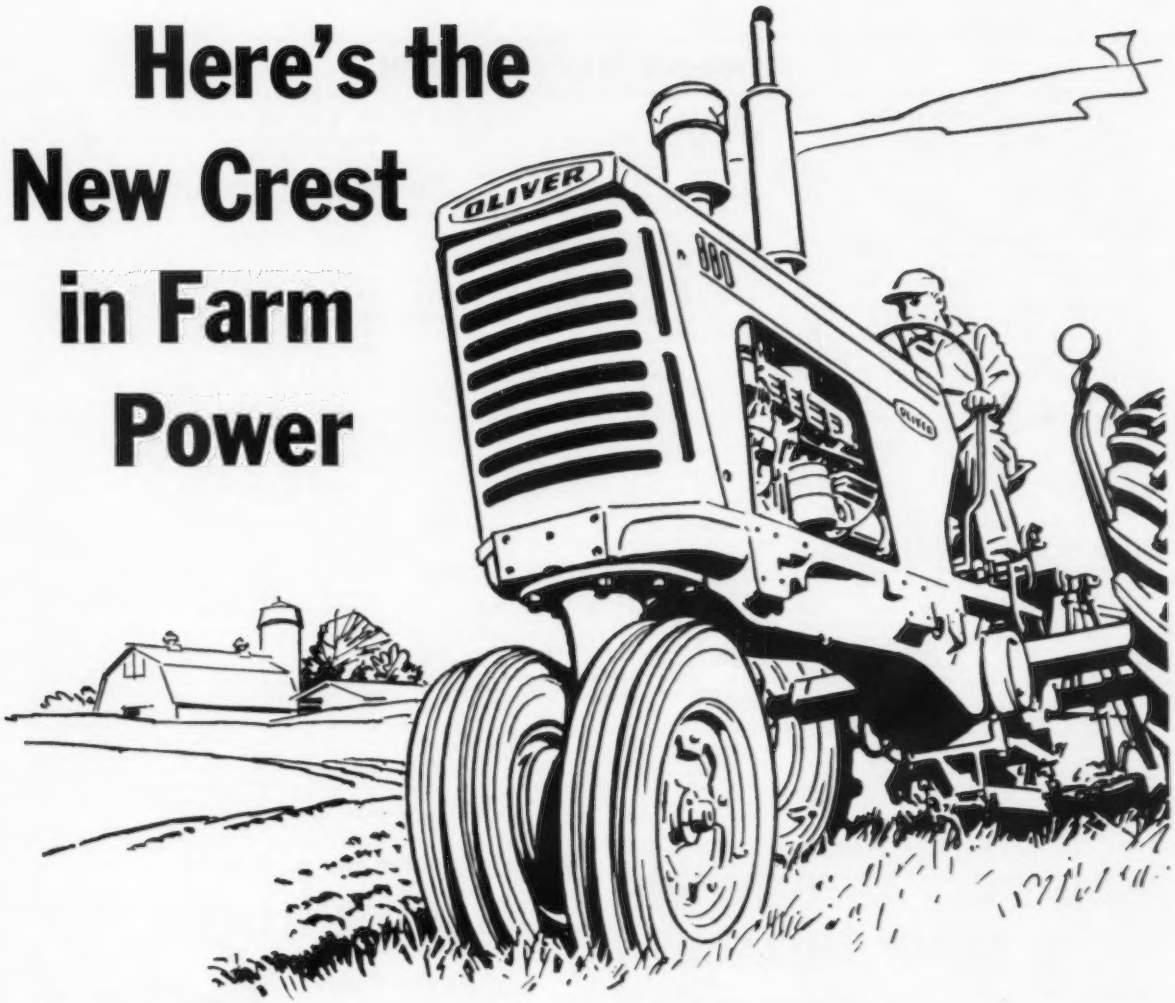
(For more facts circle No. 90 on reply card)

Tester Measures Soil Moisture and Irrigation Salinity

Industrial Instruments, Inc., by incorporating an additional scale on their BN-2 transistorized Bouyoucos soil moisture meter and using a simple sturdy probe, has provided an accurate means for measurement of irrigation water conductivity. Measurement is said to require only a few seconds. Since electrical conductivity of water is a result of dissolved salts, the instrument measures the salinity of irrigation water. The second scale measures available soil moisture.

(For more facts circle No. 91 on reply card)

Here's the New Crest in Farm Power



Again, in a brilliant new tractor fleet, Oliver has put power to work in exciting new ways to make farming easier and more efficient.

Here, from the industry's design leader, comes a bold new *look* in power. A new freshness in line, a new brightness in special colors of meadow green and clover white. And a buoyant new *feel* of power in every inch and ounce of every new model. A spirited new response from smooth, big-power engines.

There's more of everything, all around. Take the new row crop 770 and 880 models. They're up in horsepower—well over the 50 mark on the drawbar in the new 4-5 plow 880. There's new booster power in every working speed, plus more pulling power with a new hitch, power-shift wheels and power steering.

These superb new Olivers were developed to give farming a new lift, to present a new concept in the look and feel of power, to set a new standard in tractor utility.

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Designed to do everything, go anywhere. New all-purpose 550, a 2-3 plow model powered right, sized right for any farm, to handle hundreds of jobs with unusual economy.

Talk of the tractor world, and representative of Oliver's big-tractor line, is this 6-plow 995 GM Lugmatic with a truly automatic torque converter that offers 35% more lugging horsepower.

For more facts circle No. 29 on reply card

PERSONNEL SERVICE BULLETIN

PERSONNEL SERVICE BULLETIN

NOTE: In this bulletin, the following listings current and previously reported are not repeated in detail; for further information see the issue of AGRICULTURAL ENGINEERING indicated. "Agricultural Engineer" as used in these listings is not intended to imply any specific level of proficiency or registration as a professional engineer. Items published herein are summaries of mimeographed listings carried in the Personnel Service, copies of which will be furnished on request. To be listed in this Bulletin, request form for Personnel Service listings.

POSITIONS OPEN — 1957 — OCTOBER — O-314-755. NOVEMBER — O-350-756, 350-757, 360-758, 369-759, 362-760, 379-761, 380-762. DECEMBER — O-385-763, 386-764, 387-765, 412-766, 370-767. 1958—JANUARY—O-436-768, 478-769. FEBRUARY—O-12-801, 17-802, 48-803.

POSITIONS WANTED — 1957 — OCTOBER — W-341-40, 301-41, 297-42. NOVEMBER — W-337-43, 320-44, 344-45, 356-47, 357-48, 342-49, 291-50, 363-51. DECEMBER — W-371-52, 378-53, 394-54, 405-55, 409-56, 415-57. 1958 — JANUARY — W-447-58, 410-59, 381-60, 466-61, 484-62, 485-63, 3-1, 4-2. FEBRUARY — W-13-3, 21-4, 31-5, 33-6.

NEW POSITIONS OPEN

AGRICULTURAL ENGINEER, assistant or associate professor, for research and teaching in power and machinery in Hawaii. MSAE. Farm background preferred. Previous design and teaching experience desirable. Usual personal qualifications for college research and teaching. Opportunity normal to growing department. Yearly automatic raises and opportunity to earn merit raises. Usual vacation and sabbatical provisions. Salary $6,000 or higher, depending on qualifications. O-37-804

AGRICULTURAL ENGINEER, instructor or assistant professor, to teach farm shop, utilities, and farm structures, and handle other work in the agricultural engineering department of a technical college in the Southwest. BSAE. Knowledge of subject matter. Usual personal qualifications for college teaching. Nine-month contract. Opening effective September 15. Salary $4,500 - $5,000 for 9 months. O-72-805

AGRICULTURAL ENGINEERS (2) for duty with the Ministry of Agriculture, Republic of the Sudan. Age 23-45. BS, or equivalent in experience. Fully literate in English or Arabic. Three-year contract. Outfit allowance LS 50 payable when contract is signed. Cost of living allowance. Salary LS 1075-1786, according to qualifications and contract. O-78-806

GRADUATE FELLOWSHIPS (3) in cotton ginning engineering, to work for MS degree at Clemson Agricultural College. Age under 40. BSAE. Must be acceptable for admission to the Graduate School of Clemson College. Application deadline for 1958-59 school year, April 1. Stipend $2,500 for 12-month study period. O-83-807

NEW POSITIONS WANTED

AGRICULTURAL ENGINEER for sales or service in rural electric field with industry or public service. Any location. Willing to travel. Single. Age 25. No disability. BSAE, 1955, Alabama Polytechnic Institute. Farm background. Cooperative plan training in rural service engineering and electrical development from 1/53 to 9/55. Rural electric work from graduation to 3/56. Army enlisted service two years with promotion to SP-3 with field communications and general clerk experience. Available April 1. Salary $5500. W-54-7

AGRICULTURAL ENGINEER for design, development, research, sales, or service with manufacturer, distributor or consultant in power and machinery or rural electric field. Slight preference for East or Midwest. Willing to travel. Single. Age 25. No disability. BSAE expected in June, Pennsylvania State University. Farm background. Earned 100% of college expenses. Subject to call to active duty with Air Force. Available June 15. Salary open. W-36-8

AGRICULTURAL ENGINEER for teaching, research, flood control or water management in soil and water irrigation or water supply, with public service agency. Any location, some preferences for southern California. Married. Age 46. Wear glasses. BSCE, 1938, California Institute of Technology. Experience since graduation in civil engineering with private engineers, U. S. Engineering Dept. CCC Camps and flood control projects. Area engineering specialist in Southern California with USDA, 7 years. Senior engineer 3 years in charge of new agency on irrigation and drainage development in Saudi Arabia. Available about August 15. Salary $6,600 minimum. W-62-9

AGRICULTURAL ENGINEER for design, development, research, extension or teaching in farm structures, rural electric, or soil and water field with industry or public service, in South or other warm climate area (for health of son). Married. Age 36. No disability. BSAE, 1950, Louisiana State University. Farm background. USDA, SCS engineering experience 6 years. Boeing Airplane Company one year. War service in Navy 1940-46, with promotions to Chief Petty Officer. Available April 1. Salary $450 per month. W-46-10

ENGINEERING ECONOMIST for extension, teaching, research, sales or management in farm structures or product processing with industry or public service. Anywhere in U.S.A. BS in agriculture, 1957; MS in agricultural economics expected in 1958, University of Connecticut. Married. Age 27. No disability. Varied study and experience in engineering and related machine shop work including service experience in Air Force as assistant to Post Engineer; industrial experience in heat treating, forging, pressing, grinding, tumbling, and related machine operation; research assistant and instructor in agricultural engineering. Available June 13. Salary $6,000. W-74-11

AGRICULTURAL ENGINEER for teaching, sales or service in public service or industry, power and machinery field, preferably Southeast location. Married. Age 47. No disability. BSA, 1941, major in agricultural engineering, Ohio State University. Farm background. Building construction experience. Teaching experience in country school and in Navy. Engineering department of Chrysler Corporation, 1944-45. With major implement manufacturer since 1945 as service manager, machine shipper and district manager. Available in 30 days. Salary open. W-80-12

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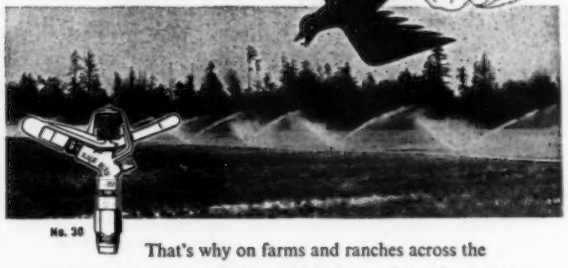

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. . . With ASAE Sections

(Continued from page 178)

of J. I. Case Co., Racine, Wis. They will talk on research in power and machinery and the inter-relation of sales and engineering in merchandising, respectively.

Mid-Central Section

The Mid-Central Section meeting will be held March 28 and 29 at the Hotel Robidoux, St. Joseph, Mo.

Symposiums will be held on subjects covering teaching, research and extension; crop production; structures; crop conditioning and storage; and automation in agriculture. A business meeting will conclude the meeting.

Officers for the coming year are George H. Larson, chairman; Hobart Beresford, Lester F. Larsen and Fred Venrick, vice-chairmen; and Ted L. Willrich, secretary-treasurer.

Connecticut Valley Section

The meeting of the Connecticut Valley Section will be held April 2 at Storrs, Conn. The program will include a tour of the agricultural engineering facilities and the University of Connecticut. Following the tour, dinner will be at the Nathan Hale Hotel in Willimantic, Conn. ASAE President, Earl D. Anderson, will be the speaker for the evening program and will talk on reducing the odds in farming. J. L. Butt, executive secretary of ASAE, will report the latest news from ASAE headquarters.

Washington D.C. Section

Sam R. Hoover, Eastern Utilization Research and Development Div., ARS, U.S. Department of Agriculture, will speak on new developments in the utilization of farm products at the April 11 luncheon meeting of the Washington D.C. Section.

A tour of the University of Maryland is being arranged by the agricultural engineering department to observe new developments in engineering research at the University for the May 9 meeting.

Alabama Section

The Alabama Section will meet at the Whitley Hotel in Montgomery, Ala., April 17 and 18. The program will be devoted to the engineering problems of supplying electric power to rural areas, controls for electric motors and processing equipment, the development of water sources for Alabama agriculture and the development of marketing facilities for agricultural products.

The Thursday morning, April 17, schedule includes registration and tours of Hazel Atlas Glass Co., Alaga Syrup and W. W. Pickle Co. The afternoon program will stress reports in the field of rural electrification with papers on engineering aspects of supplying electricity to a rural area by P. C. O'Shee, grounding and lightning protection by Marlin Harris, environmental conditions needed for comfort in homes by Walt Grub, and controls used in farm application by Frank Graf. A banquet is planned for the evening with Judge J. Ed Livingston, chief justice of Alabama Supreme Court, as speaker.

Friday morning, April 18, the program will consist of papers on water supplies and agriculture by M. R. Williams, furrow irrigation by H. Bouwer, planning and design of the Georgia State Farmer's Market by Sam Hurst, and agricultural aspects of developing a farm market by Clinton Johns.

. . . Events Calendar

(Continued from page 177)

May 19 — A regional meeting of *Engineers Joint Council*, sponsored locally by the Western Society of Engineers, will be held at the Sherman Hotel in Chicago, Ill. For further information contact either Engineers Joint Council, 29 W. 39th St., New York 18, N. Y., or Western Society of Engineers, 84 E. Randolph St., Chicago 1, Ill.

June 17-20 — Joint meeting of the *American Grassland Council* and the *American Dairy Science Association*, Raleigh, N. C. For further information write to Z. W. Craine, Sec'y-Treas., American Grassland Council, P.O. Box 30, Norwich, N. Y.

. . . Membership Applicants

(Continued from page 185)

Staudt, Calvin C. — Student, Pennsylvania State University (Mail) R.R. 1, Wernersville, Pa.

Washburn, Gene N. — Student, University of Arkansas (Mail) R.R. 1, Fayetteville, Ark.

Watson, James H. — Student, Kansas State College (Mail) Coldwater, Kans.

Wilkerson, Carnie C. — Student, Oklahoma State University (Mail) R.R. 1, Wetumka, Okla.

Wolford, Wayne E. — Student, University of Nebraska (Mail) 2945 S. 27th, Lincoln, Nebr.

Yates, Paul—Student, University of Tennessee (Mail) 535 Morganton Rd., Maryville, Tenn.

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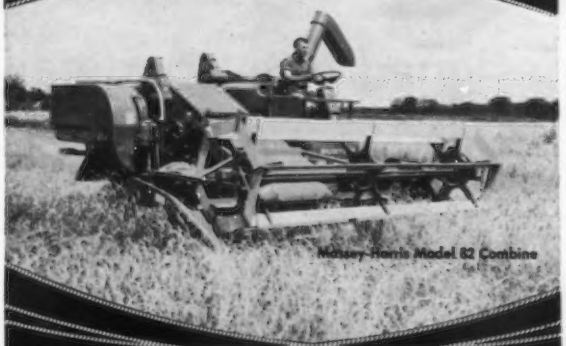

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For more facts circle No. 35 on reply card

Index to Advertisers

Aetna Ball & Roller Bearing Co. 133
Aluminum Co. of America 143
American Zinc Institute 192
Armco Steel Corp. 131
Automotive Gear Div., Eaton Mfg. Co. 183
Bearings Co. of America Div., Federal-Mogul-Bower Bearings, Inc. ....2nd cover
Behlen Mfg. Co. 179
Bendix Products Div., Bendix Aviation Corp. 181
Blood Brothers Machine Div., Rockwell Spring & Axle Co. 150
Deere & Company 144, 145
The Deniston Co. 190
Farm Fans Div., Ewing Foundry, Inc. ... 194
Federal-Mogul Div., Federal-Mogul-Bower Bearings, Inc. 146
Hyatt Bearings Div., General Motors Corp. 136
International Harvester Co. 134
Lincoln Engineering Co. 129
Link-Belt Company 139, 189
Locke Steel Chain Co. 195
National Rain Bird Sales and Engineering Corp. 194
National Seal Div., Federal-Mogul-Bower Bearings, Inc. 135
Neapco Products, Inc. 140
New Departure, Div. of General Motors ..... 3rd cover

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New Holland Machine Co. 186
New Idea Farm Equipment Co. 191
The Oliver Corp. 193
Rockford Clutch Div., Borg-Warner Corp. 184
Ross Gear & Tool Co., Inc. 147
Spraying Systems Co. 196
Stephens-Adamson Mfg. Co., Sealmaster Div. 142
Stephens-Adamson Mfg. Co., Spherco Bearings Div. 149
Stow Mfg. Co. 185
Stran-Steel Corp. 141
The Texas Company 148
Timken Roller Bearing Co. ..... 4th cover
University of California Press. 196
Whitney Chain Co. 132
Wisconsin Motor Corp. 182

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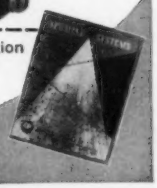

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The Literature of Agricultural Research

by J. Richard Blanchard and Harald Ostvold

This annotated, descriptive guide to reference works in the field of agriculture is an attempt to meet the information-locating problems posed by the proliferation of agricultural literature in recent years. The fields covered include much of interest to agricultural engineers. J. Richard Blanchard is Librarian, University of California, Davis, and Harald Ostvold is Chief, Science and Technology Division, New York Public Library.

242 pages, $5.00

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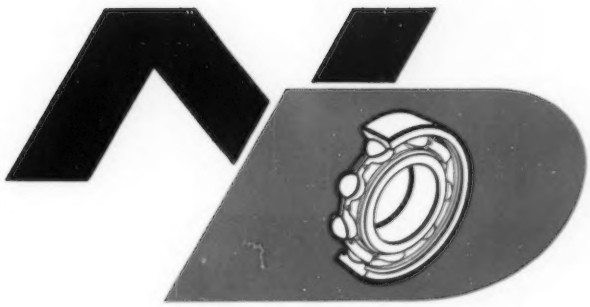

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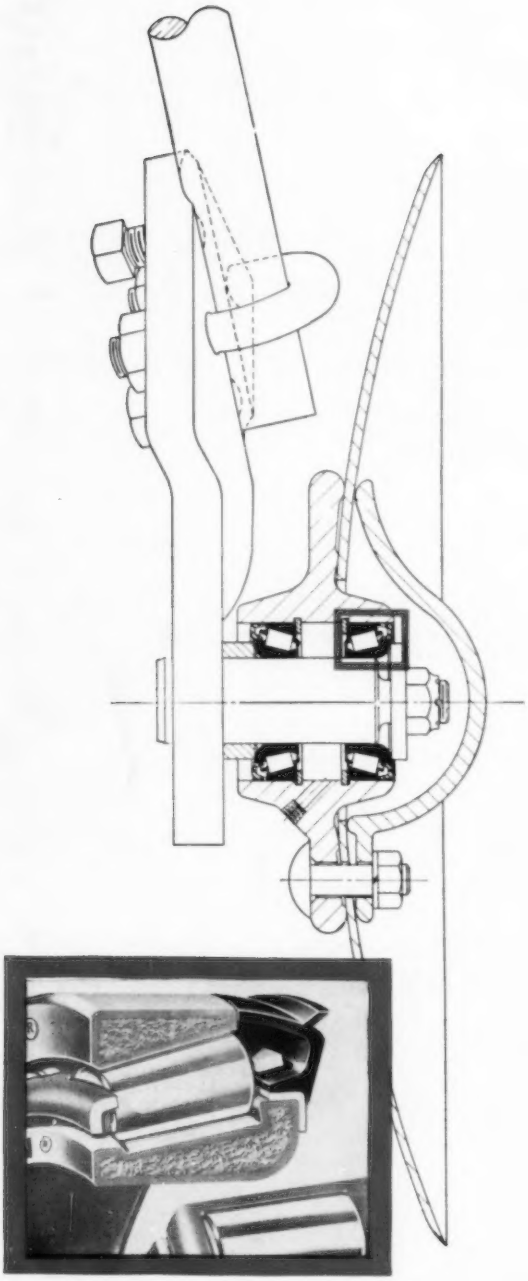
For more facts circle No. 3 on reply card

Disc jointer manufacturer switches to Timken® bearings with new "Duo-face" seal



Gets 2-way sealing, cuts assembly costs, saves space

ALREADY major implement manufacturers are switching to Timken® bearings with the new Duo-face seal, introduced only last August. This new seal does a better job because it seals two ways. It reduces assembly costs because it comes already assembled on the bearing inner race. And it also saves space because it adds practically nothing to the width of the bearing. How one manufacturer is using it on a disc jointer is shown at left.

SEALS 2 WAYS. The new Duo-face is the only anti-friction bearing seal combining the advantages of an O.D. and a face type seal. One lip of the seal operates against the bearing housing bore, providing an O.D. seal. The other against the smooth, flat, hardened surface of the bearing cup face.

CUTS ASSEMBLY COSTS. Pre-assembly of the seal on the cone eliminates mounting of the seal and bearing in separate operations. There are no special handling or assembly problems. No special tools or fixtures are needed. There are no extra installation costs. And when the bearing is removed from a machine there's less chance of damaging the seal.

SAVES SPACE. The new Duo-face seal takes up less space than conventional seals, permits more compact hub and housing designs. Yet it does not limit lubricant capacity.

PROVED PERFORMANCE. The Timken Company Duo-face seal has been field-tested and proved on tractor front wheels, implement wheels, disc jointers, disc plows, disc harrows, coulters, side delivery hay rakes and conveyor idlers.

Timken bearings with assembled Duo-face seals are available in the following bore sizes: .7500″, .8437″, 1.0000″, 1.2500″, 1.3750″, 1.5000″ and 2.6875″. For information, call your nearby Timken Company sales engineer or write: The Timken Roller Bearing Company, Canton 6, Ohio. Canadian plant: St. Thomas, Ontario. Cable address: "TIMROSCO".

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